Iron AND Steel ENGINEER

ENGINEERING SERVICE
TO THE IRON AND STEEL
INDUSTRY SINCE 1907

DECEMBER, 1949

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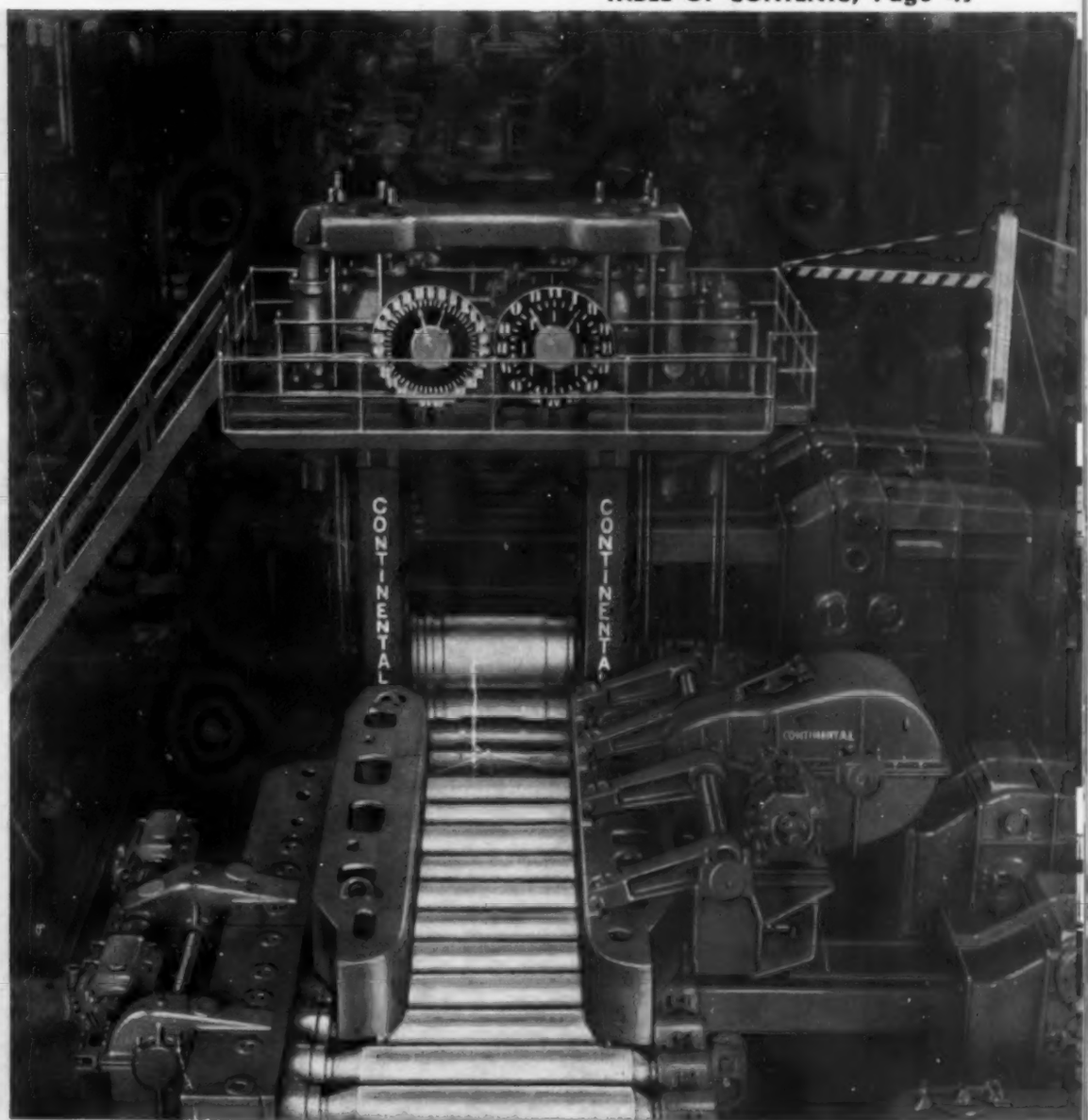
TECHNOLOGY DEPT.

COMPLETE INSTALLATIONS OF ROLLING MILLS AND STEEL PLANT EQUIPMENT

including:

Blooming Mills
Structural Mills
Bar Mills
Billet Mills
Merchant Mills
Plate Mills
Slabbing Mills
Universal Mills
Hot Strip Mills
Cold Strip Mills
Non-Ferrous Mills
Roll Lathes
Ingot Mold Cars
Charging Box Cars
Transfer Cars

and other steel plant equipment, accessories and special machinery



Shop view of a High Lift 40" Reversing Blooming-Slabbing Mill

Continental

FOUNDRY & MACHINE CO.

CHICAGO · PITTSBURGH

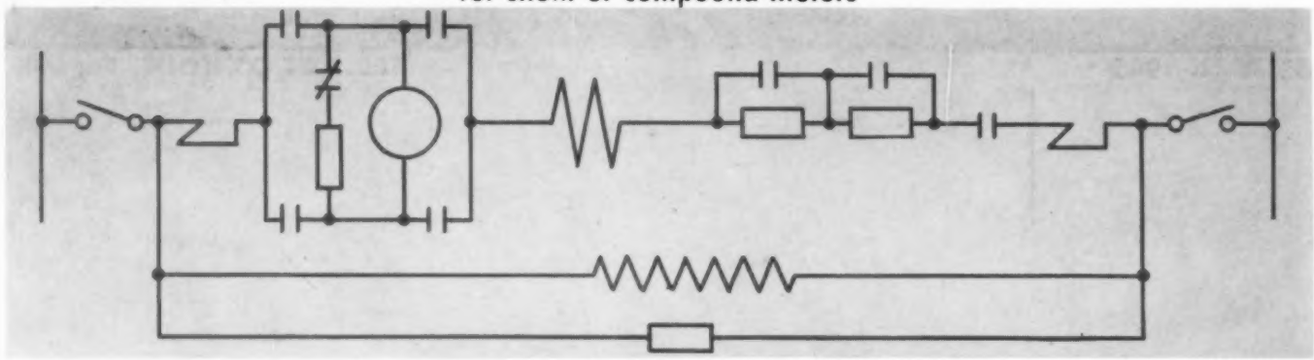
Plants at E. Chicago, Ind. Wheeling, W. Va. Pittsburgh, Pa.

Complete Rolling Mills and Auxiliary Equipment
Iron, Alloy Iron and Steel Rolls for all Industries.
Steel Castings from 20 to 250,000 pounds

What control for what mill equipment? One of a SERIES of advertisements featuring basic heavy duty power circuits . . . and showing Cutler-Hammer's broad design and application experience which has made it *the* preferred control for the steel industry.

D. C. reversing dynamic braking control

for shunt or compound motors

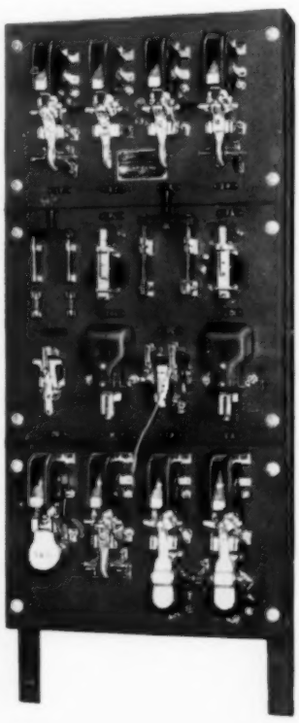


When you have an installation such as a sheet leveler where load and performance characteristics dictate the use of a reversible shunt or compound motor with dynamic braking . . .

Here . . . call for Cutler-Hammer Control No. 14017

Engineering features . . Cutler-Hammer Bulletin No. 14017 provides smooth, uniform *Ltl* acceleration, simplified dynamic braking and controlled plugging, for quick stop and rapid reversal. Also, when speed control by field weakening is required, Bulletin 14017 provides additional motor protection such as field accelerating, field decelerating, field economizer and field loss relays. It employs dependable constant timing *Ltl* contactors which have a coarse and a micrometer adjustment, not affected by dust and dirt. New type 609 overload relay provides inverse time delay for running protection and instantaneous trip for excessive loads.

CONTROL COMPONENTS . . . Every component in Cutler-Hammer Control is built with extreme ruggedness to provide an unusual margin of reserve. Characteristic of C-H Control construction is its simplicity and the absence of light moving contacts and parts, spring adjustments, etc., that commonly cause trouble.



EQUIPMENT . . . Conforming to NEMA standards. Available in ratings to 1800 amperes. In open, enclosed or complete factory assembled ready to wire units. A complete line of control accessories.

TO A DEGREE perhaps not equalled elsewhere, maintenance in the steel industry is costly because of the consequent loss of time and production. To a degree not equalled elsewhere, "steel" wages unceasing warfare on maintenance, placing highest value on durability and dependability of equipment. And it cannot escape the eye of shrewd production-minded management that it is in "steel" . . . in 50 years of "steel" . . . that Cutler-Hammer equipment has so largely built its world-wide reputation for dependability.

CUTLER-HAMMER, Inc., 1269 St. Paul Ave., Milwaukee 1, Wis. *Associate:* Canadian Cutler-Hammer, Ltd., Toronto.

CUTLER-HAMMER
MOTOR CONTROL
C-H

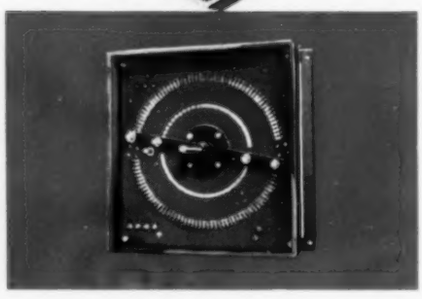
Typical Components of Cutler-Hammer Mill Control

Rotating Cam Limit Switch (cover removed)

Wide range heavy duty uses. Wearing parts oversize. Hardened cam face and roller surfaces. Main shaft ball bearings. Easy, accurate driving shaft adjustment in any position.

Pushbutton Station

Wide range of styles including oil-tight construction. No loops in wiring these large rugged terminals. Oversize mushroom type operating buttons. Drip hoods. Guard flanges.



Field Rheostats

50 or 100 speed points. Manual, chain or motor operated. Renewable brass segments. Rugged long life construction. Single step unit type renewable resistors.

IRON AND STEEL ENGINEER, published monthly by Association of Iron and Steel Engineers, 1010 Empire Bldg., ·tered as second class matter January 25, 1924 at Pittsburgh, Pennsylvania, under Act of Congress March 3, 1879. $7.50 per year in United States and Canada, $10.00 foreign countries. Volume 26, No 12.

Exclusive with...

Aetna-Standard

PUBLIC LIBRARY
DEC 21 1949
DETROIT

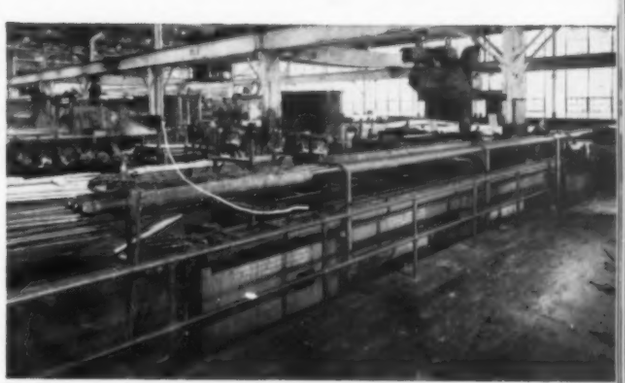
triple drawing of tubes

Figure with your own pencil the multiple production and cost-cutting advantages of drawing three tubes simultaneously!

Production with triple draw will be 2½ to 3 times as great as with your present single draw methods. This has been proven by the many triple tube drawbenches now in operation.

Benches now in operation are drawing tubes 1/8" to 3" diameter with a pulling capacity of 1000 lbs. to 100,000 lbs. Lengths of draw are up to 160 ft. Triple drawbenches with up to 300,000 lbs. pull are now being offered by Aetna-Standard.

Triple drawing of tubes is an exclusive development of Aetna-Standard. Write us for more about triple drawing.



DESIGNERS AND BUILDERS to the Steel, Non-Ferrous and Chemical Industries

THE AETNA-STANDARD ENGINEERING COMPANY
YOUNGSTOWN, OHIO

ASSOCIATED COMPANIES:
HEAD, WRIGHTSON & COMPANY, LTD., THORNABY-ON-TEES, ENGLAND
AETNA-STANDARD ENGINEERING COMPANY, LTD., TORONTO, ONTARIO, CANADA

Answer:

To the rail maker, the bumper bar manufacturer, producers of strip sheet and all other steel fabricators, National Rolls are all alike in one respect. They are precision-finished rolls that meet their specifications and exceed their expectations for dependability on the stands.

In producing all National iron and alloy iron rolls quality is controlled from start to finish. Only the best materials and workmanship go into them. That is why you get the most out of them. Try National Rolls and see.

National Rolls

THE NATIONAL ROLL & FOUNDRY CO.

AVONMORE, PENNSYLVANIA

SPECIALISTS IN IRON AND ALLOY IRON ROLLS AND CASTINGS

Assure a Reduction in Reduction Gear Upkeep

Gears last longer when they have the EXTRA PROTECTION of Texaco Meropa Lubricants

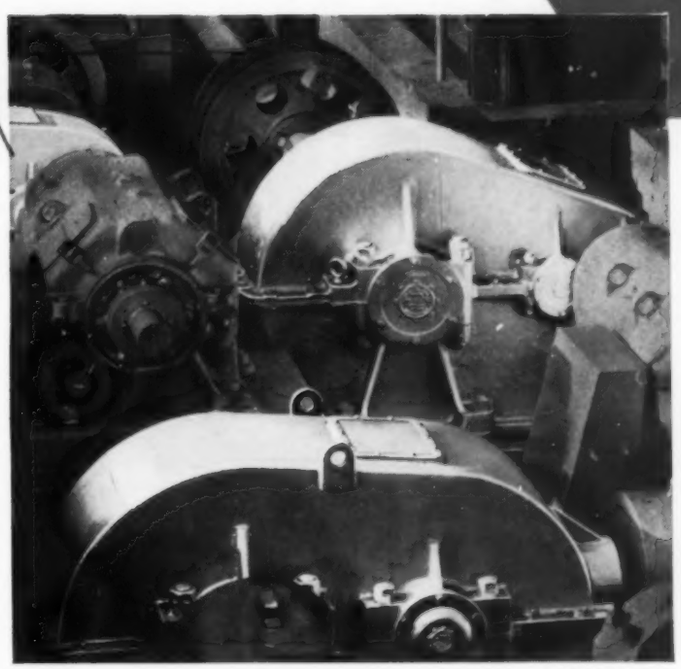


Photo courtesy Link-Belt Company

Cushion the load on your heavy-duty enclosed gears with *Texaco Meropa Lubricants* and gain three benefits: 1) smoother, more trouble-free operation; 2) longer life for both gears and bearings; and 3) lower maintenance costs.

Long-lasting *Texaco Meropa Lubricants* are especially made to maintain a clinging, protective film on the gear teeth and to protect bearings. They strongly resist oxidation and thickening . . . do not foam . . . do not separate in service or storage.

In circulating systems for oil film roll necks, use *Texaco Regal Oils*. These heavy, turbine-grade oils stand up under high temperatures . . . resist oxidation, emulsification and sludging . . . keep the system *clean*.

A Texaco Lubrication Engineer will gladly help you increase efficiency and economy in all your operations. Just call the nearest of the more than 2300 Texaco Wholesale Distributing Plants in the 48 States, or write:

The Texas Company, 135 East 42nd Street, New York 17, N. Y.

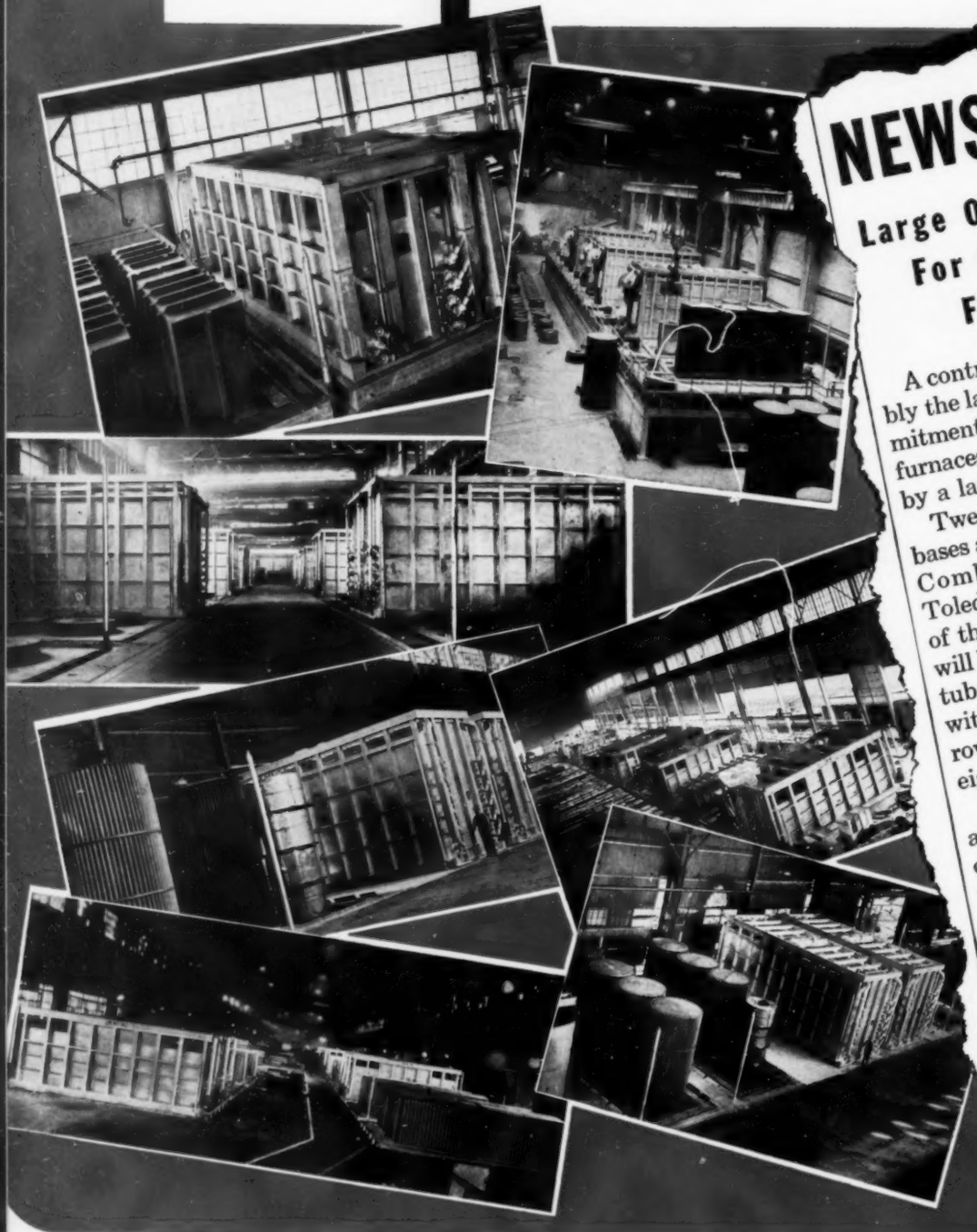
TEXACO

TEXACO Meropa Lubricants

FOR STEEL MILL GEAR DRIVES

TEXACO STAR THEATRE PRESENTS MILTON BERLE ON TELEVISION EVERY TUESDAY NIGHT. METROPOLITAN OPERA BROADCASTS EVERY SATURDAY AFTERNOON.

for years ... the choice



NEWS ITEM

Large Order Placed For Annealing Furnaces

A contract for what is probably the largest single such commitment for coil annealing furnaces was recently placed by a large steel company.

Twenty furnaces and sixty bases are to be built by Surface Combustion Corporation, Toledo, Ohio, under the terms of this contract. The furnaces will be of the horizontal radiant tube type and will be arranged with the sixty bases in a double row, each base accommodating eight stands of coils.

The annealing covers will accommodate coils 67 inches in outside diameter which may be piled to a maximum height of 148 inches. Total charge of coiled steel per base is approximately 450 tons. This means that as much as 27,000 tons of steel may be in process at any one time.

It is believed that this is the largest single contract for such equipment ever let by a steel company.

'Surface' SERVES THE STEEL INDUSTRY

ce of leading steel mills ★

SURFACE COMBUSTION CORPORATION • TOLEDO 1, OHIO

FOREIGN AFFILIATE COMPANIES

BRITISH FURNACES LIMITED—CHESTERFIELD
STEIN & ATKINSON, LTD.—LONDON

STEIN & ROUBAIX—PARIS, LEIGE AND GENOA
WILL L. SMITH, S.A.—BUENOS AIRES

One-Way Fired Soaking Pits

Billet Reheating Furnaces

Slab Heating Furnaces

Continuous Type, Controlled Atmosphere Strip Annealing and Normalizing Furnaces

Controlled Atmosphere Annealing Covers for Wire and Rod

Controlled Atmosphere Annealing Covers for Coil and Sheets

Continuous Furnaces for Heat Treatment of Steel Plate

Controlled Atmosphere Furnaces for Carbon Correction in High Alloy Rod and Bar Stock

Continuous Type Bright Annealing and Normalizing Furnaces

Prepared Gas Atmosphere Generating Equipment

Pit Type Convection Furnaces for Rod Annealing

Stress Relief Furnaces

Wire Patenting Furnaces

ANOTHER QUALITY FEATURE IN...

ELLIOTT

FABRI-STEEL

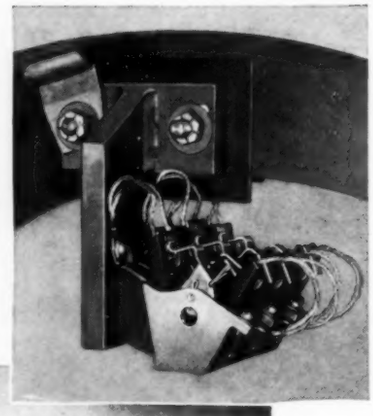
D-C MOTORS

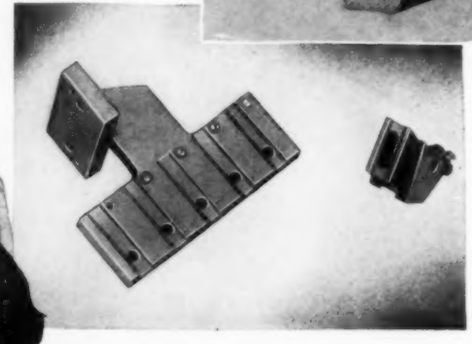
An exceptionally dependable, accurate and simple

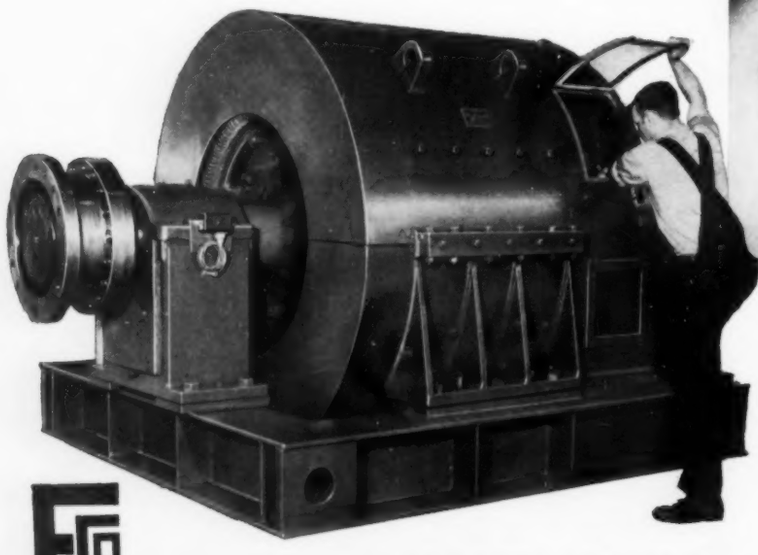
brush rigging

The brush yoke in Elliott DC Motors fits into frame supports bored concentric with the bore of the frame, assuring concentricity of yoke with frame and commutator. The brushholder bracket, machined to close tolerance, is fitted to the brush yoke, positioned with a special fixture for spacing and angle, then bolted and doweled to the brush yoke. Canvas phenolic plates, tubing and dowels provide insulation between bracket and yoke.

Each brushholder fits in a machined groove in the bracket. When the commutator wears, the loosening of one bolt in each brushholder permits it to be slid down its groove for correct clearance without affecting its original spacing or angular setting. Just one more of the numerous features that throughout the steel industry are making "Elliott Fabri-Steel" synonymous with forward-thinking motor and generator development.







Removable, hinged, quick-opening doors, of clear plastic, to get at commutator and brushes.

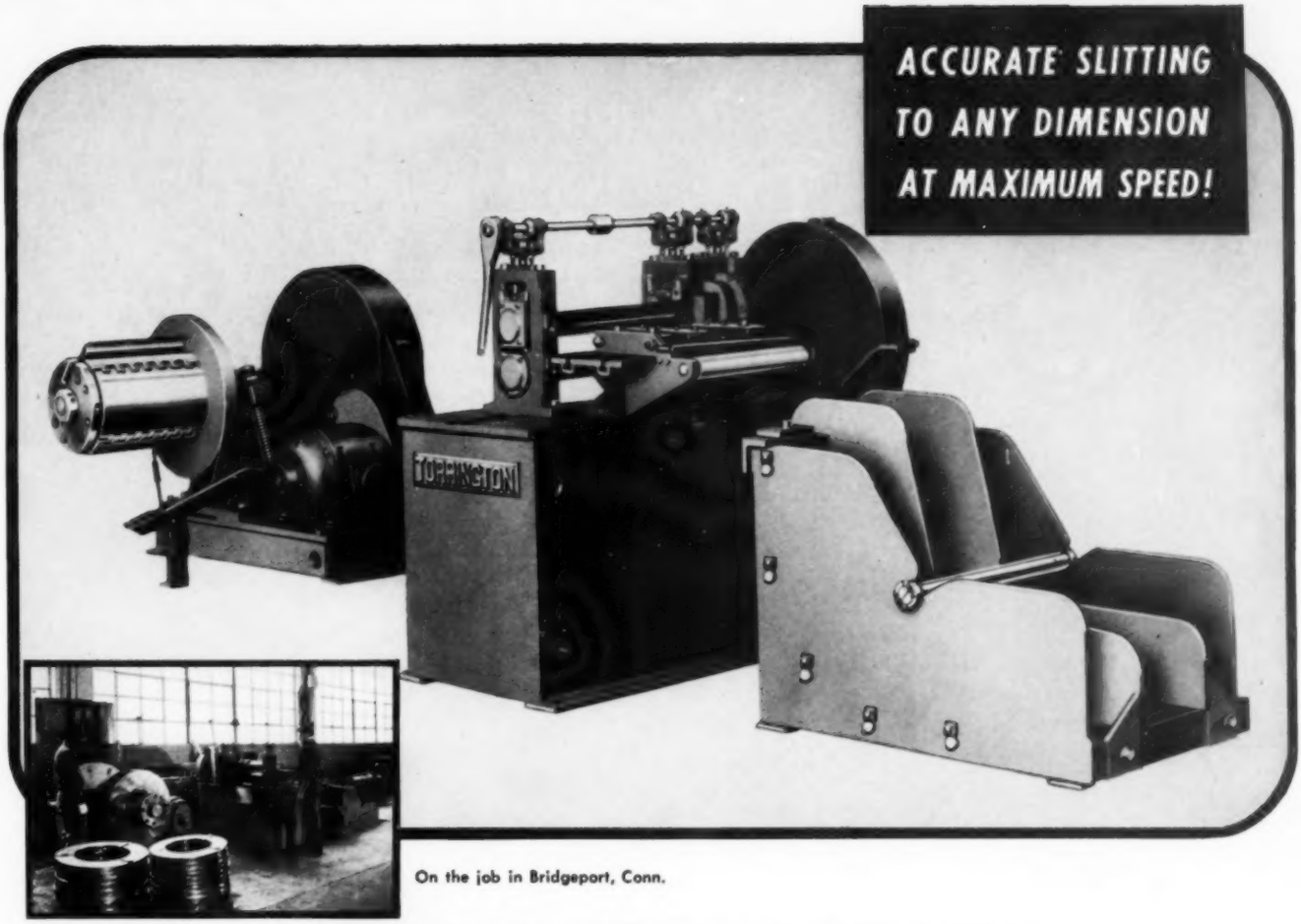
For full details on Elliott Fabri-Steel DC Motors, write to:

MR-5

ELLIOTT COMPANY DEPT. I-S, RIDGWAY DIVISION RIDGWAY, PA.

Plants in JEANNETTE, PA., RIDGWAY, PA., AMPERE, N. J., SPRINGFIELD, OHIO, NEWARK, N. J.

DISTRICT OFFICES IN PRINCIPAL CITIES



On the job in Bridgeport, Conn.

TORRINGTON'S *HIGH-SPEED* SLITTING LINE
Converts wide stock to any desired dimension!

★ Motor-driven slitter for threading up!

★ Winder with automatic collapsible block!

★ Arranged for pull-through operation!

★ Anti-friction bearings used throughout!

These compact, easily operated Torrington machines have been designed to meet the needs of users who require slitters which can be quickly set up and operated with minimum time and effort.

Here are just a few of your advantages with a Torrington Slitter on the job: 1. Ability to secure metals in wide widths quickly! 2. Elimination of large and unbalanced inventories of cut-to-width materials! 3. Quicker deliveries on shorter notice because of broader source of supply! 4. Instant availability of slitter to convert wide stock to any dimensions for daily production needs!

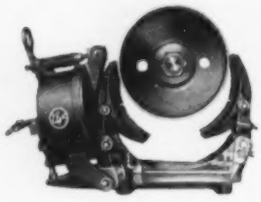
The sturdy construction of Torrington Slitters assures years of continuous, dependable service. With the proper tool set-up, you can hold widths within the limit of .001", plus or minus.

Call or write Torrington today for more information and name of nearest Torrington representative.

The TORRINGTON
MANUFACTURING COMPANY TORRINGTON, CONNECTICUT

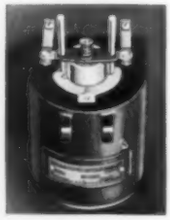
DESIGNERS AND BUILDERS OF MILL MACHINERY FOR OVER 60 YEARS

Complete Control for Cranes



LONG-LIFE Brakes give high speed performance—with low up-keep.

SHORT-THROW narrow width Cam Master switches are easy on the operator.



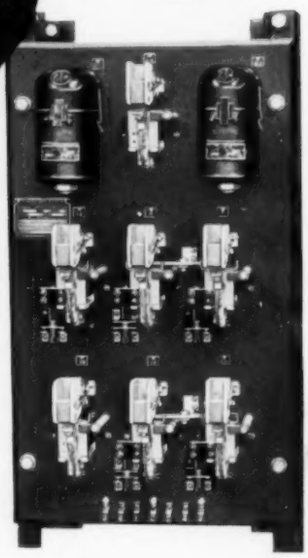
TIME - CURRENT Relay matches acceleration to the d-c load.

YOUNGSTOWN Safety Limit Stop — a positive check against human error.

Push Button Control

for A-c and D-c Floor Operated Cranes

HAS THESE ADVANTAGES



1. Designed for minimum collectors on crane.
2. Control may be mounted directly against crane girders, etc.—angle supports give proper clearance between rear of panel and mounting surface.
3. Panels hinged at bottom permit tilting when making installation connections.

Many Cranes Can Be Controlled to Advantage from the Floor.

This EC&M Control for *floor-operated* cranes has all the advantages of the well-known EC&M Control for cab-operated cranes. A single pendant master-station, with two Push Buttons for each motion, permits convenient control of all crane movements. Individual rope-operated Master Switches are optional.

Inching points, smooth operation through automatic acceleration are standard with these EC&M Controllers. Occasionally, some cranes are designed for both cab and floor operation. EC&M builds control suited to the requirements of dual operation.

For Complete Control, Specify EC&M

TAB-WELD Resistors—no burning where burning would cause high up-keep.

CRANE DISCONNECT SWITCH Manual-magnetic for ease of operation.

THE ELECTRIC CONTROLLER & MFG. CO.

2698 EAST 79TH STREET ★ CLEVELAND 4, OHIO

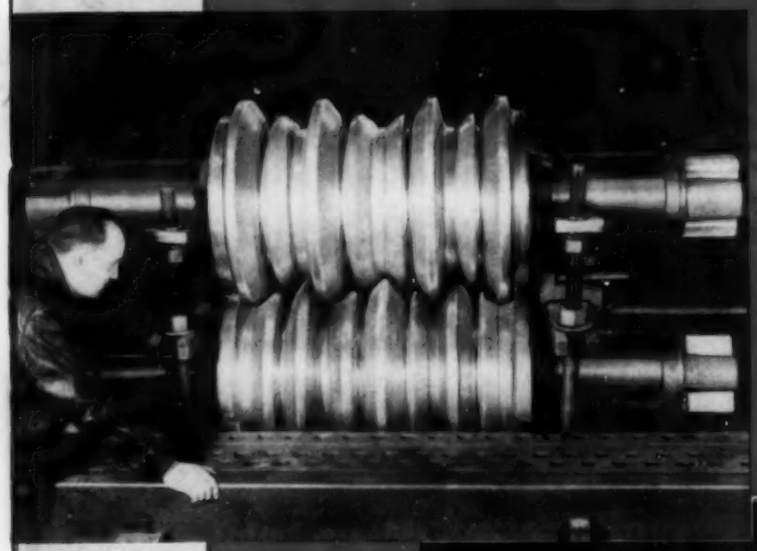
Rolls and Pinions

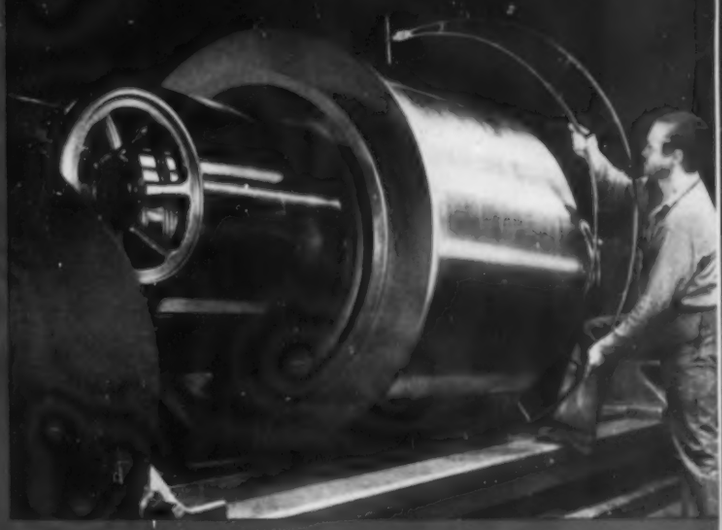
Designed and Built by

MESTA

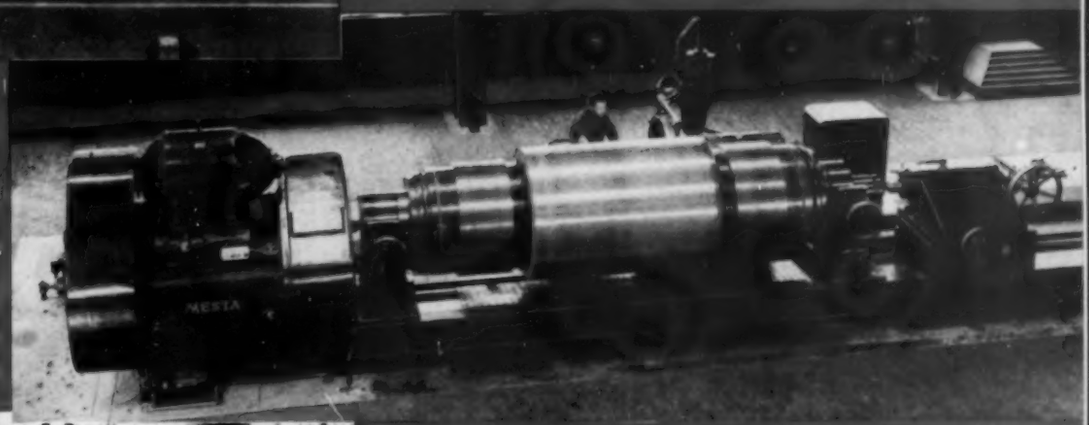
Group of Forged Hardened Electric Steel Working Rolls for Cold Reduction Mills

A pair of Mesta Merchant Mill Rolls for the production of I-Beams

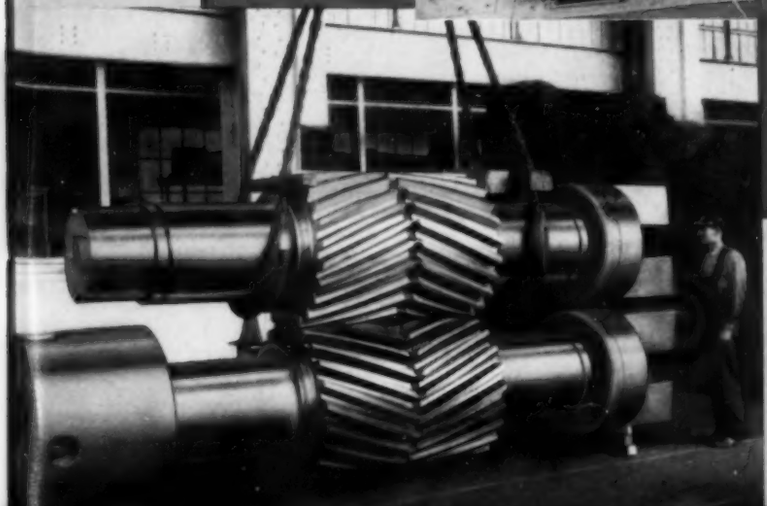




Mesta 56" diameter Special Alloy Cast Steel Backing-Up Roll for a modern high speed Four-High Cold Reduction Mill



Mesta 60" Heavy Duty Traveling Wheel Head Type Roll Grinder

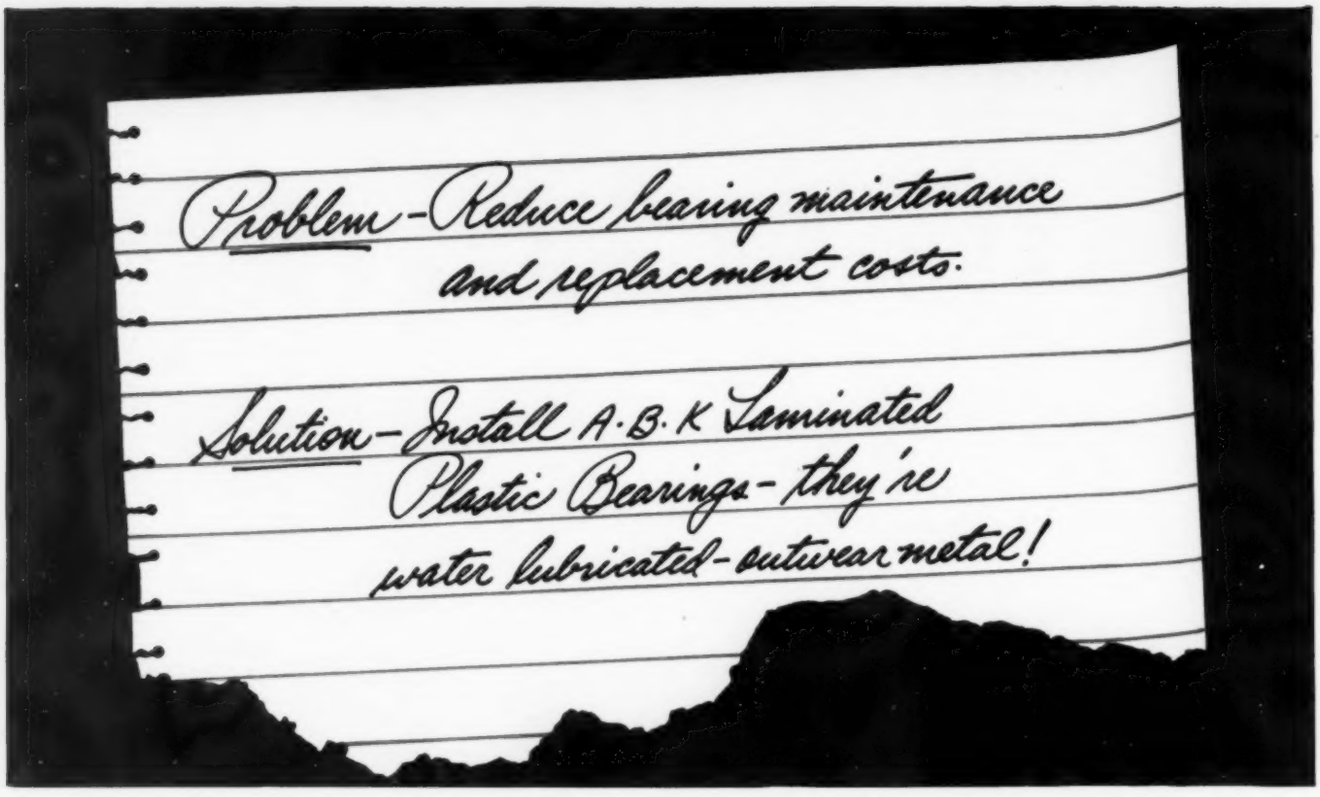


38" x 56" Forged Steel Blooming Mill Pinions
Mesta also produces Cast Steel Mill Pinions with cut or molded teet

Designers and Builders of Complete Steel Plants

MESTA MACHINE COMPANY

PITTSBURGH, PA.


Problem - Reduce bearing maintenance and replacement costs.
Solution - Install A·B·K Laminated Plastic Bearings - they're water lubricated - outwear metal!

● When A-B-K Laminated Plastic Bearings replace conventional steel mill bearings, savings begin *immediately.*

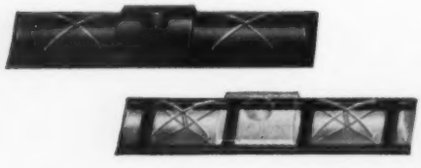
First, cost of lubricating oil is eliminated entirely. A-B-K bearings are successfully lubricated with *water.*

Second, A-B-K bearings cut power consumption from the start.

Third, A-B-K bearings hold gauge longer —require fewer adjustments—reduce costly shutdowns.

Fourth, A-B-K Laminated Plastic Bearings actually outwear metallic bearings. The material in these bearings is exceptionally tough and slow-wearing. It will not distort under shock and is highly heat-resistant. Actually polishes—never scores—the shaft!

Add up these advantages of A-B-K Laminated Plastic Bearings in terms of dollars and cents *saved.* An A-B-K representative, backed by the vast research and engineering facilities of our organization, will be glad to tell you how A-B-K bearings can cut costs on specific applications in your mill. Write for a consultation.



Above: A-B-K slipper bearing, with phantom view showing patented reinforced edge.
Right: A-B-K roller neck bearing with separate collar.

A·B·K
Laminated Plastic Bearings

AMERICAN Brake Shoe COMPANY

AMERICAN BRAKEBLOK DIVISION
DETROIT 9, MICHIGAN

Steel tonnage rolled in 1948 weighs over three times as much as Grand Coulee Dam

ALL the concrete in this giant dam weighs less than a third of the steel rolled in the United States in a single year! This vast tonnage went into strip, plates, rails, structural shapes, tubular products, bar and many other forms. An important share of this production passed through rolls with the long-established P.R.W. mark on the wabbler.

For every rolling mill requirement, Pittsburgh Rolls produces rolls that, in the way they perform, the way they stand up under modern mill conditions, daily prove their inbuilt superiority. They are produced with just one thought in mind . . . *less cost per ton of steel rolled!*

PITTSBURGH ROLLS • Division of Blaw-Knox Company • Pittsburgh 1, Pa.

PITTSBURGH ROLLS

*COLOR

For maximum production . . . top efficiency . . . lowest operating cost, give your machines the finest in lubricants—give them Tycol oils and greases.

Tycol lubricants are made to meet every lubrication need of industry—from roll neck greases for steel mills to spindle oils for textile plants.

Each Tycol lubricant is subjected to rigid tests during manufacture. This control assures the required lubrication characteristics—*COLOR, penetration, viscosity, to name a few—for maximum performance of that particular product. At every step from selection of crudes to blending of the finished product, Tycol lubricants provide maximum lubricating efficiency which means greater economy, longer life for every type of equipment.

Tide Water Associated will be glad to assist you in selecting the Tycol lubricant best suited to your specific need. Call or write your nearest office for further details.

TYCOL
INDUSTRIAL LUBRICANTS

Boston • Charlotte, N. C. • Pittsburgh • Philadelphia • Chicago
Detroit • Tulsa • Cleveland
San Francisco • Toronto, Canada

TIDE WATER ASSOCIATED OIL COMPANY
17 BATTERY PLACE - NEW YORK 4, N. Y.

*LEARN WHAT THIS PRODUCT CHARA ISTIC MEANS TO YOU — READ "LUBRICANIA"
This informative handbook, "Tide Wate: ssociated Lubricania," gives clear, concise descriptions of the basic tests used to determine important properties of oils and greases. For your free copy, write to Tide Water Associated Oil Company, 17 Battery Place, New York 4, N. Y.

REFINERS AND MARKETERS OF VEEDOL — THE WORLD'S MOST FAMOUS MOTOR OIL

How 456 TIMKEN® bearings help smooth your sheets

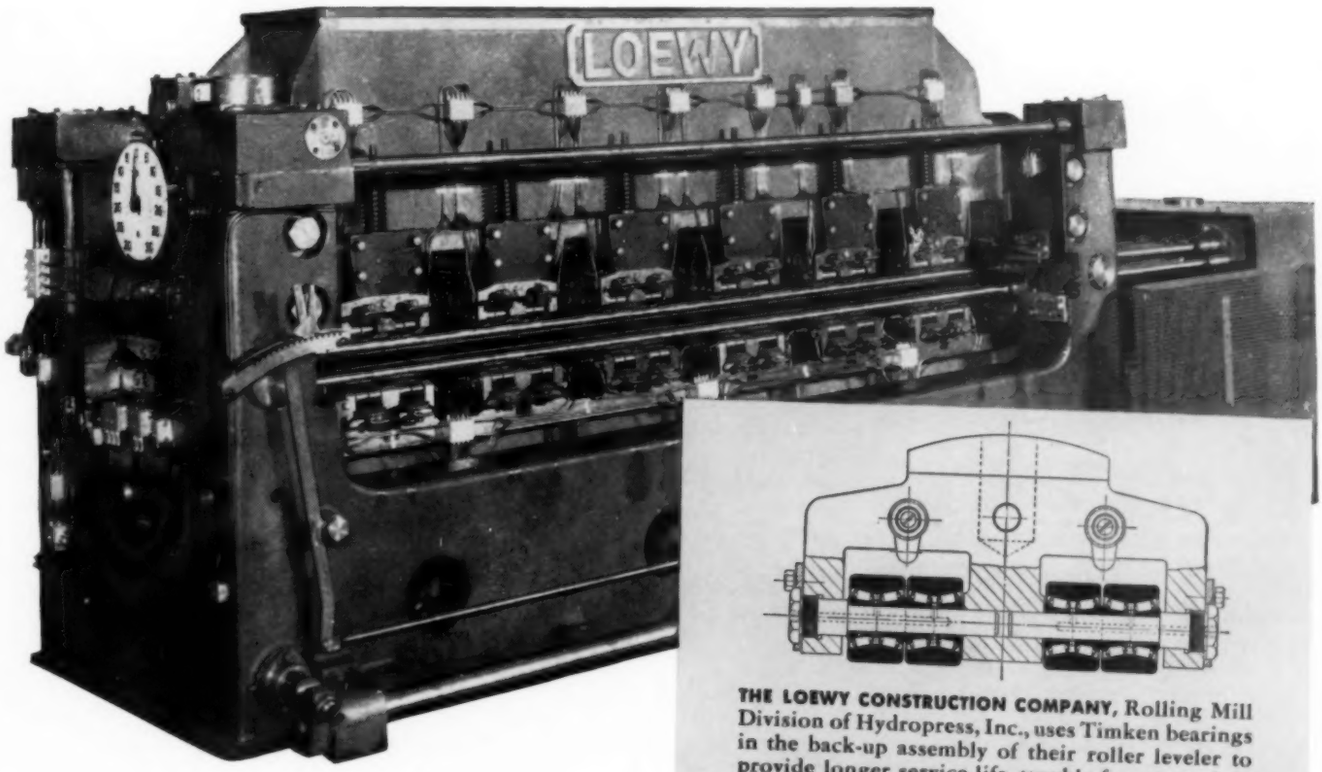
STRAIGHTENING steel sheets is the job of this roller leveler manufactured by the Loewy Construction Company, Rolling Mill Division of Hydropress, Inc., New York. 456 Timken® tapered roller bearings on the back-up rolls assure long trouble-free service life in spite of the tremendous radial loads involved in the leveling operation.

Due to the tapered construction of Timken bearings, they carry any combination of radial and thrust loads. Maximum load capacity is provided by line contact between the rolls and races.

Manufactured to extreme precision and finished to incredible smoothness, Timken bearings make friction practically negligible. Tighter closures are permitted and lubricants are more effectively retained. And since Timken bearings are made of the finest steel ever developed for tapered roller bearings—Timken fine alloy steel—they normally last the life of the machine.

50 years of bearing research and development stand behind Timken bearings—first choice throughout industry. No other bearing can give you *all* the advantages you get with Timken bearings. Whether you build or buy machinery, always look for the trade-mark "Timken" on the bearings. The Timken Roller Bearing Company, Canton 6, Ohio.

This symbol on a product means its bearings are the best.



THE LOEWY CONSTRUCTION COMPANY, Rolling Mill Division of Hydropress, Inc., uses Timken bearings in the back-up assembly of their roller leveler to provide longer service life, trouble-free operation.

POSITIVE ROLLER ALIGNMENT

Wide area contact between roll ends and rib of the cone prevent Timken roller bearings from skewing. Result: bearings roll easier, last longer.

The Timken Company is the acknowledged leader in: 1. advanced design; 2. precision manufacture; 3. rigid quality control; 4. special analysis steels.

TIMKEN

TRADE MARK REG. U. S. PAT. OFF.

TAPERED ROLLER BEARINGS

TIMKEN 1899 50 1949 YEARS

NOT JUST A BALL ○ NOT JUST A ROLLER ⬭ THE TIMKEN TAPERED ROLLER ⬭ BEARING TAKES RADIAL ◎ AND THRUST →◎← LOADS OR ANY COMBINATION →✳←

new drive for 66" continuous pickling line permits faster acceleration, cuts maintenance costs!

General Electric-engineered drive simplifies operation, reduces downtime, helps increase strip steel output!

Of outstanding interest to steel mill operators is a new 66-inch high-speed continuous pickling line now in operation in a large Eastern mill. Electrically engineered, co-ordinated, and equipped by General Electric, it provides important features such as these to increase output and cut costs:

Acceleration rates up! Amplidyne control of separate adjustable-voltage generators for the entry and delivery ends makes possible much faster acceleration and deceleration, limited only by the commutating ability of the motors and generators.

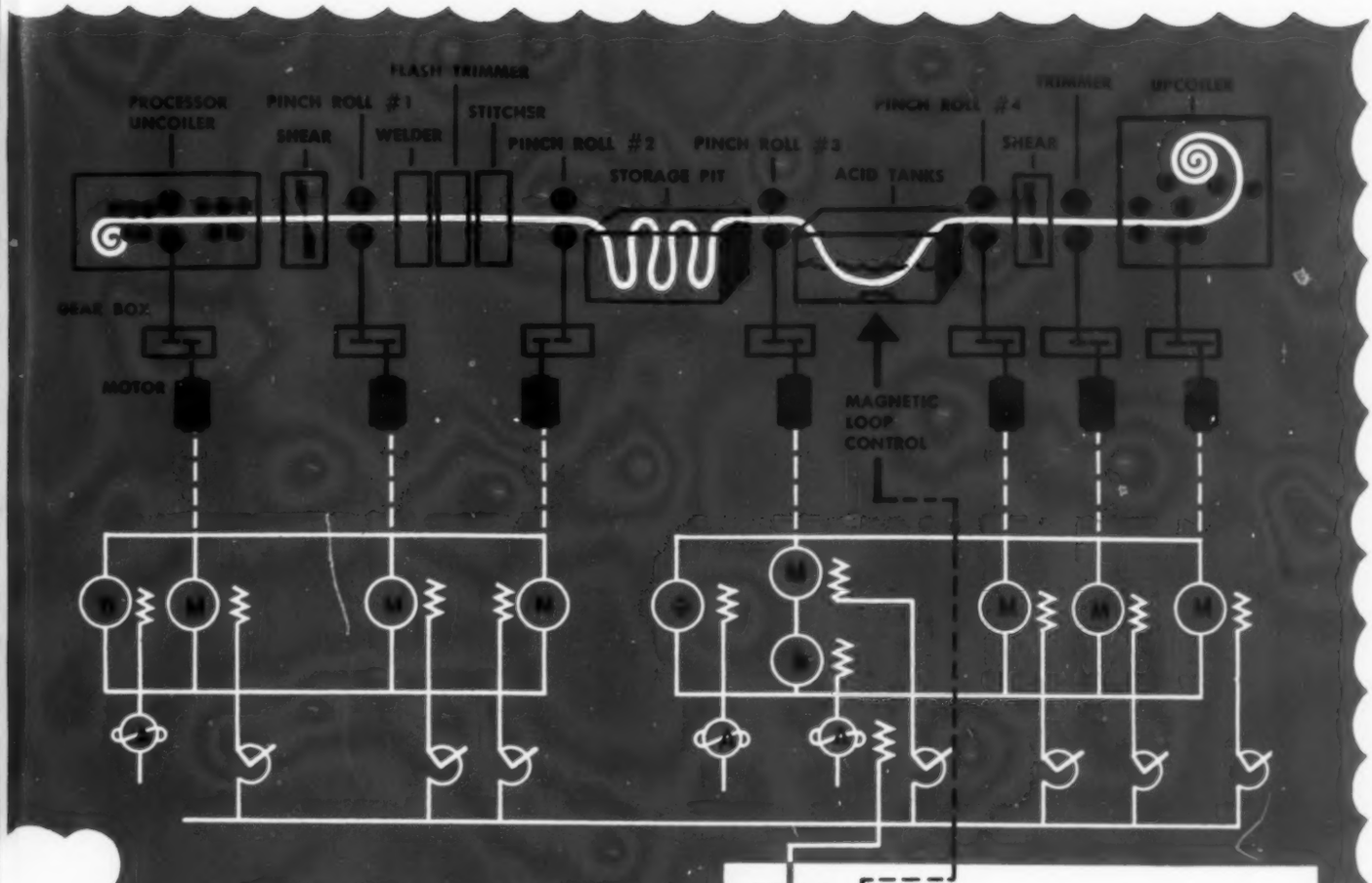
Maintenance costs down! A new magnetic loop control utilizing for the first time the Amplistat—General Electric's new static magnetic amplifier—regulates the loop position in the pickling tank. By regulating the loop position without the use of dancer rolls or dancer roll rheostats, the problem of corrosion of these rolls and rheostats—and resulting costly downtime—is eliminated.

Output increased! Faster acceleration and deceleration of the drive makes it easier for operators at the entry end to keep up with the delivery end, simplifies operation, and helps maintain a higher rate of output.

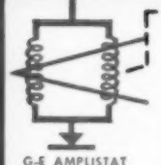
Here is further proof that—whatever *your* drive problem—experienced G-E engineering can help turn it into a successful installation. A G-E steel mill specialist will be glad to discuss it with your technical staff. Phone him at your nearest G-E office. *Apparatus Dept., General Electric Company, Schenectady 5, N. Y.*

GENERAL ELECTRIC

659-41



HERE'S HOW IT'S ENGINEERED!



The drive motors (M) for the various machines which make up this continuous pickling line are divided into an entry section and a delivery section. Each section is supplied by an individual generator, making it possible to operate them independently. Each generator (G) is excited by an amplidyne exciter (A), which regulates voltage and provides current limit for rapid acceleration and deceleration. Speed adjustment of individual machines in each section is accomplished by motor field control. A magnetic loop control regulator automatically maintains the position of the strip catenary in the acid tanks. The signal produced by the pick-up unit is amplified first by an Amplistat and then by an amplidyne exciter. The amplidyne excites a booster generator (B) in series with No. 3 pinch roll motor, and thus controls the speed of No. 3 pinch roll to correctly position the strip.

Shown here are the flash welder and entry-end control desk. The tail end of each coil is welded to the front end of succeeding coils in order to provide an endless strip through the pickling tanks. Delivery strip speed is 600 FPM, making this G-E equipped line one of the industry's fastest.

another example of GENERAL ELECTRIC drive engineering at work!

WHEN YOU'RE FIGURING CABLE COSTS* USE THESE FACTS ON FILE ABOUT OKONITE

4700 feet of Okonite Underground Cable in service since 1908..... Removed and Re-Used in 1948

2000 feet of Okovar Varnished Cambric Cable Installed Overhead and put in service in 1927..... Removed and Re-Used in 1948.

***with today's installation costs only the *Longest-Lived* will be economical . . . . . .**

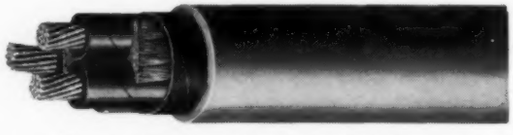
The lifetime cost of a cable rather than its first cost is the only true measure. Okonite wires and cables, built to stand up better and longer, can offset high installation costs.

In the files of The Okonite Company are a number of case histories that tell their own story of the long life—the real yardstick of cable economy—that you can count on with Okonite. The two instances cited above are from the records of a single customer.

They are two of eleven instances of cables long used and transferred to new locations by this customer, who has re-installed more than 24 miles of such Okonite cable.

Building true value into cable has been Okonite's business since 1878. What goes into an Okonite cable to make it do a better job...what tests it must pass...what care is taken to control its electrical characteristics—all this and other data are found in Research Bulletin IS-101. For a copy, address The Okonite Company, Passaic, New Jersey.

Okonite rubber insulated lead-covered underground cable.

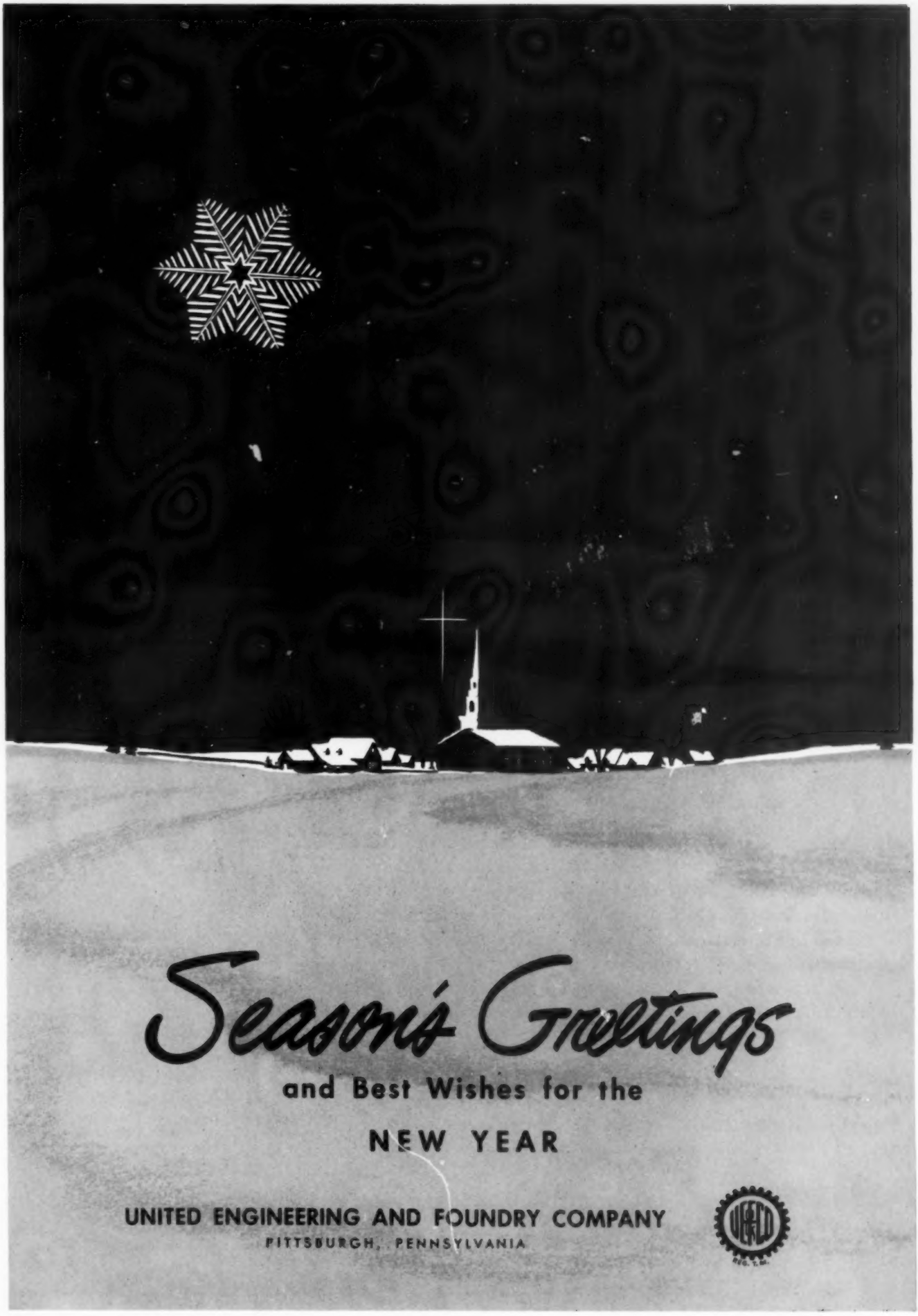


Okovar varnished cambric lead-covered aerial power cable.

THE BEST CABLE IS YOUR BEST POLICY

7421

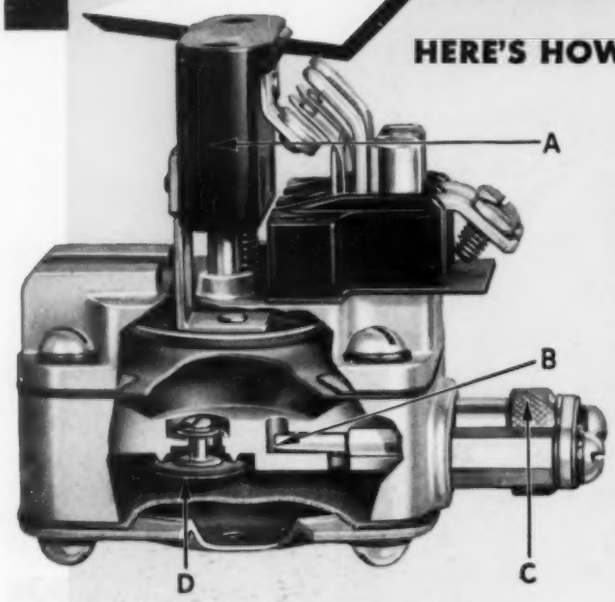
OKONITE OKONITE SINCE 1878 ***insulated wires and cables***


Season's Greetings
and Best Wishes for the
NEW YEAR
UNITED ENGINEERING AND FOUNDRY COMPANY
PITTSBURGH, PENNSYLVANIA

PNEUMATIC TIMERS Do It Better

ACCELERATE MILL MOTORS ... and CONTROL AUTOMATIC PROCESSES

HERE'S HOW THEY WORK



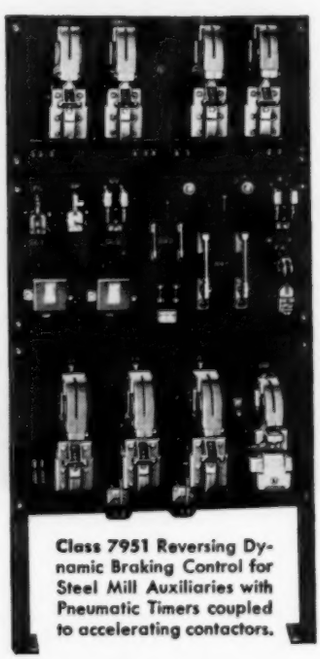
Timing head can be coupled to a contactor or actuated by separate magnet. Contact member (A) is normally pushed down against compression spring. When contact member is released, a rubber diaphragm is flexed upward, drawing air from lower chamber to upper chamber through metering orifice (B). Rotation of knurled wheel (C) advances or withdraws pin to give wide range adjustment. Air returns through valve (D) for instantaneous reset. Lower diaphragm is double layer felt.

Square D's PNEUMATIC TIMERS, a product of over 10 years' experience in many difficult fields of application, offer these proven design and performance features.

- **Extremely accurate**
- **Adjustable over wide range**
- **Unaffected by dust or usual fluctuations in voltage or temperature**
- **Dependable over long periods of severe service**
- **Simple, flexible and easily applied**
- **Attached to contactors or actuated by separate magnet**

• Accurate, fixed timing insures uniform motor acceleration under all conditions of application. Operators are able to obtain closer control by anticipating machine response. Unusually wide range adjustment permits choice of timing period to cover any acceleration requirement.

Processing of steel and associated materials consists of many individual operations performed in timed sequence. (For example—the interval allowed for dumping a blast furnace skip bucket before the hopper rotates.) Pneumatic timers are available for time-delay making or time-delay breaking of a circuit after either energization or de-energization of contactor or separate magnet. Their use in an automatic control circuit simplifies equipment and provides the accuracy and reliability essential to efficient performance.



Class 7951 Reversing Dynamic Braking Control for Steel Mill Auxiliaries with Pneumatic Timers coupled to accelerating contactors.

Write for Class 7950 series bulletin on Heavy Duty D.C. Control for Cranes and Mill Auxiliaries. Square D Company, 4041 North Richards Street, Milwaukee 12, Wisconsin.

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A new arc welding machine catalog— Welders for AC, DC, gas engine operation —capacities of 100 to 500 amperes.

Here, at last, is a helpful booklet that gives you complete data on all Airco arc welders — the machines with the stinger that penetrates. Divided into easy-to-read sections, you can quickly determine the welder suited to your production or maintenance job.

This booklet is handy, useful, bringing you a wealth of information covering design, distinctive features, specifications, power requirements, electrical characteristics, and outstanding operational qualities of each welder in the entire Airco line.

To give you some idea of the amount of material covered by this definitive booklet, here are a few of the many welders covered.

- "Bumblebee" and MCT — Transformer AC Arc Welding Machines
- "Hornet" 36A and "Wasp" — DC Arc Welding Machines
- "Yellow Jacket" Gas-Engine Driven Arc Welders
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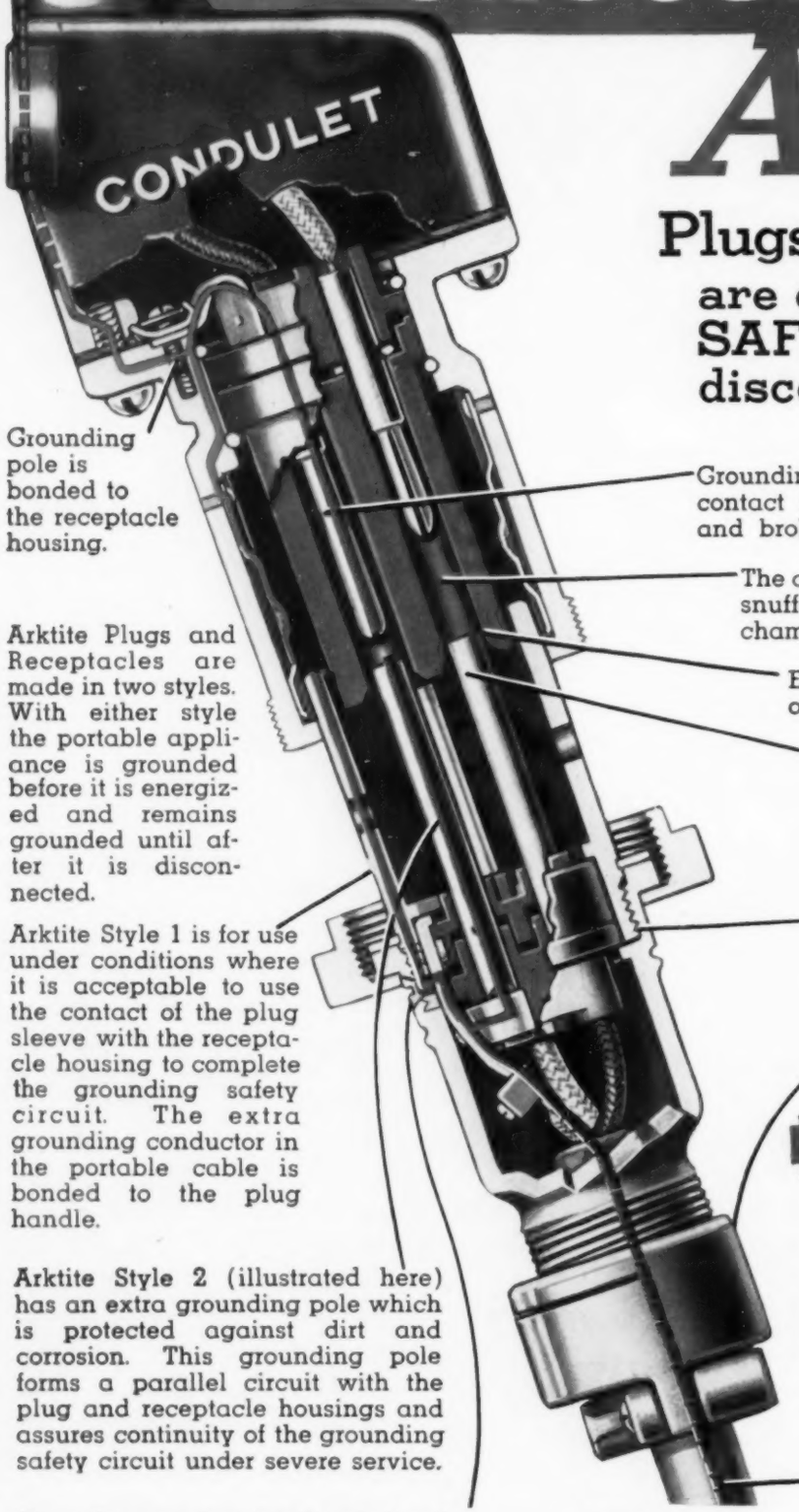
Arktite

Plugs and Receptacles

are circuit breaking and SAFE without additional disconnect equipment.



Grounding pole is bonded to the receptacle housing.

Arktite Plugs and Receptacles are made in two styles. With either style the portable appliance is grounded before it is energized and remains grounded until after it is disconnected.

Arktite Style 1 is for use under conditions where it is acceptable to use the contact of the plug sleeve with the receptacle housing to complete the grounding safety circuit. The extra grounding conductor in the portable cable is bonded to the plug handle.

Arktite Style 2 (illustrated here) has an extra grounding pole which is protected against dirt and corrosion. This grounding pole forms a parallel circuit with the plug and receptacle housings and assures continuity of the grounding safety circuit under severe service.

Grounding conductor is bonded to the plug handle.

Arktite Style 2. Sectional View

Grounding pole is longer than the others so contact in the grounding circuit is made first and broken last.

The arc formed by pulling the plug is instantly snuffed in the confined insulated arcing chamber.

Each plug contact fits closely the opening of its individual arcing chamber.

The arc is broken while the plug contact is still a considerable distance inside of the arcing chamber. There is no danger of the arc traveling over to the other side of the circuit or to the housing.

Two-piece plug is easy to take apart and reassemble.

Direct-pressure clamp insures positive grip on the conductor cable.

CROUSE-HINDS offers the only complete line of circuit breaking plugs and receptacles—20 Amp. to 400 Amp., 250 volt D.C., 600 volt A.C.

Complete listings are in the Condulet Catalog.

The green line indicates the grounding safety circuit.

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Since 1923, when Farrel Heavy Duty Roll Grinders were first placed on the market, hundreds of these machines have been installed in steel and nonferrous rolling mills. One major steel company alone has twenty-two in continual, every-day use.

Farrel-Birmingham engineers explain the success of these machines by pointing out that *they provide for all five of the major essentials of modern-day roll finishing.*

1. HIGH PRODUCTION—Reports from users indicate that with the latest type machines they are able to cut roll grinding time substantially, and at the same time obtain rolls with a perfect surface free from marks of any kind.

2. FINE FINISH — Rolls can be ground to any desired finish which can be obtained with wheels at present available.

3. REDUCED LABOR AND ROLL COSTS —Faster grinding means less labor per roll. In addition, rolls have longer life because the exceptionally smooth and vibration-free action in roll, wheel and traverse drives means less metal has to be removed to clean up a roll in roughing and finishing operations. This reduces the frequency of roll replacement and, consequently, the investment in new rolls.

4. CONTINUOUS DEPENDABILITY— The best proof of the dependability of the Farrel Roll Grinder is found in the tendency of users of one machine to buy a second, third and more machines as their production requirements increase.

5. RANGE OF APPLICATIONS — The Farrel Roll Grinder finishes all types of rolls (chilled iron, alloy iron, steel, brass, rubber, granite, etc.) used in the rolling of any sheet materials, as well as other cylindrical parts requiring accuracy within close limits.

Write for a free copy of Bulletin No. 115 which shows why this machine is able to provide this unique 'five-point performance.'

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FB-553

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"Buffalo" Rubber-Lined Exhausters last three to twelve times as long on the job as ordinary fans.

If you want a "fan of many lives" for removing your dangerous fumes, you'll find it in the "Buffalo" line.

Why not write for Bulletin 2424-E now and get all the facts? Or ask your nearby "Buffalo" engineering representative.

CORROSIVE FUMES Can't Contact Metal!

This cross-section of the "Buffalo" fan housing shows how rubber layer effectively shields all interior metal fan parts from fumes.

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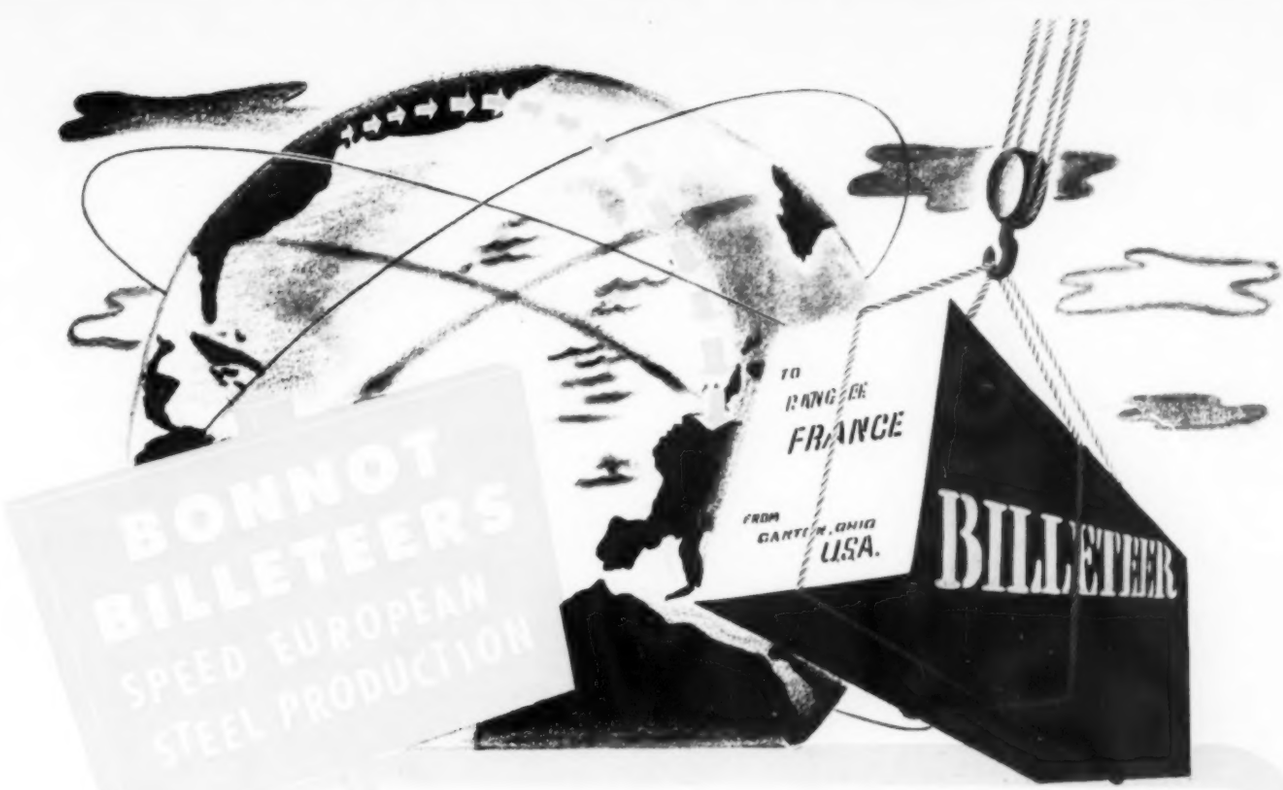

Still more Bonnot Billeteers are on the way to Europe to join those already speeding steel production for industrial recovery. Plants receiving the new Billeteers in the near future are located in Belgium, Luxemburg, Italy and France.

World-wide acclaim for the Billeteer lies in what the Billeteer is doing for every plant in which it is installed. The billet shed was once the bottleneck between furnaces and shipping docks. Today with Bonnot Billeteers, deep flaws can be cut out and remelting of billets is practically eliminated—there's a steady flow of clean billets to finishing mills. Operating records show a Billeteer handling 100 tons of billets per shift—removing up to 1½ tons of steel scrap—all flaws completely eliminated—all chips 100% reclaimable.

Just one operator handles the Billeteers easily during an 8-hour shift, doing the work of more than 10 hand chippers and without the fatigue and manpower turnover that results from more muscular methods of billet cleaning. Why not let the Bonnot Billeteer work for you? Write for information today!

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The Bonnot Co.
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Piping men everywhere know the advantages to be gained by standardizing on Crane. It's the **One Source of Supply** complete enough to simplify every piping procedure. **One Responsibility** for all materials helps to assure better installations, avoids needless delays. And for the **High Quality** in every item that makes for dependable and durable piping systems, there's no better source to turn to than Crane.

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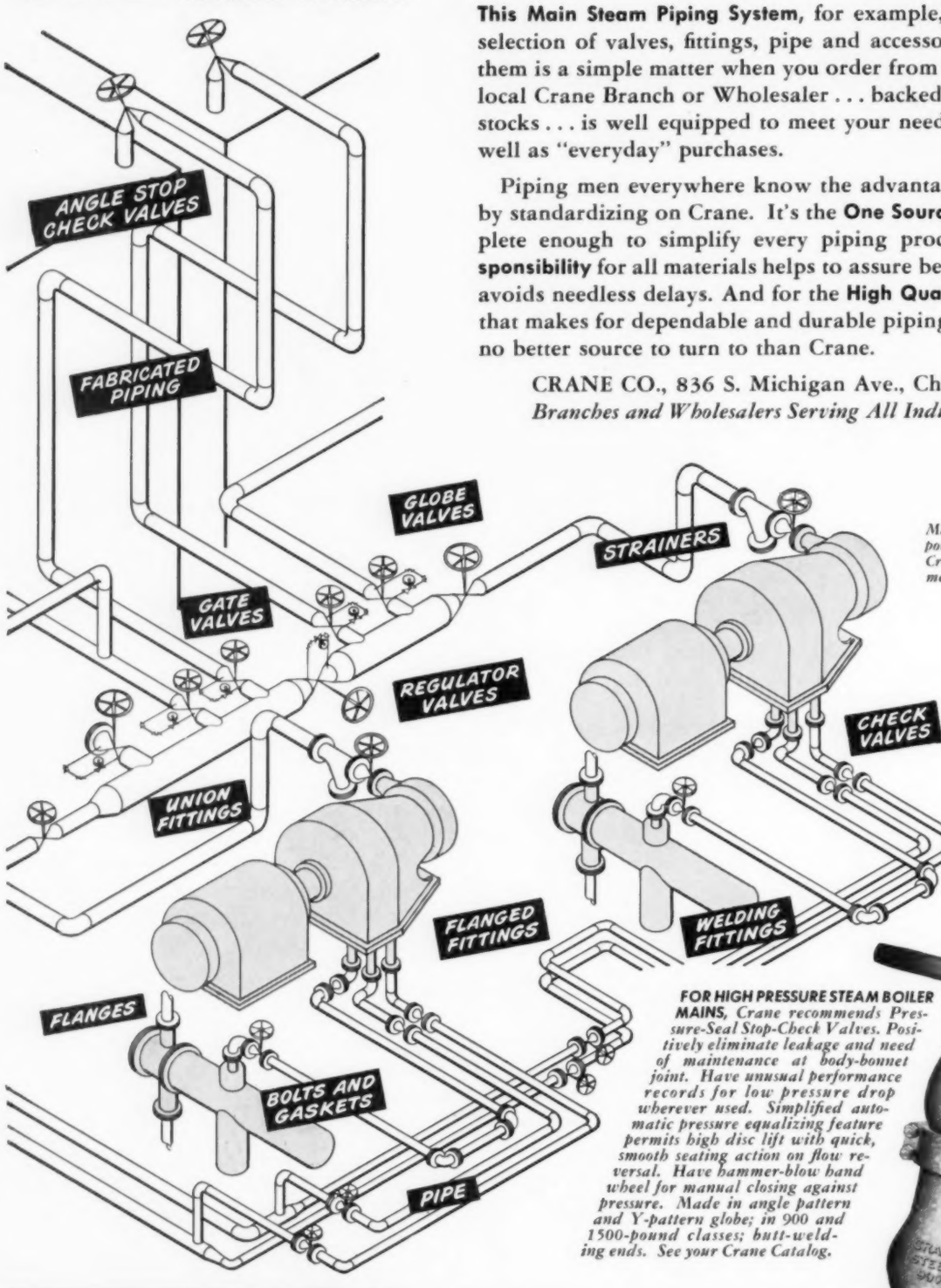

Main steam lines in a large power plant: one order to Crane gets all piping equipment.

FOR HIGH PRESSURE STEAM BOILER MAINS, *Crane recommends Pressure-Seal Stop-Check Valves. Positively eliminate leakage and need of maintenance at body-bonnet joint. Have unusual performance records for low pressure drop wherever used. Simplified automatic pressure equalizing feature permits high disc lift with quick, smooth seating action on flow reversal. Have hammer-blow hand wheel for manual closing against pressure. Made in angle pattern and Y-pattern globe; in 900 and 1500-pound classes; butt-welding ends. See your Crane Catalog.*

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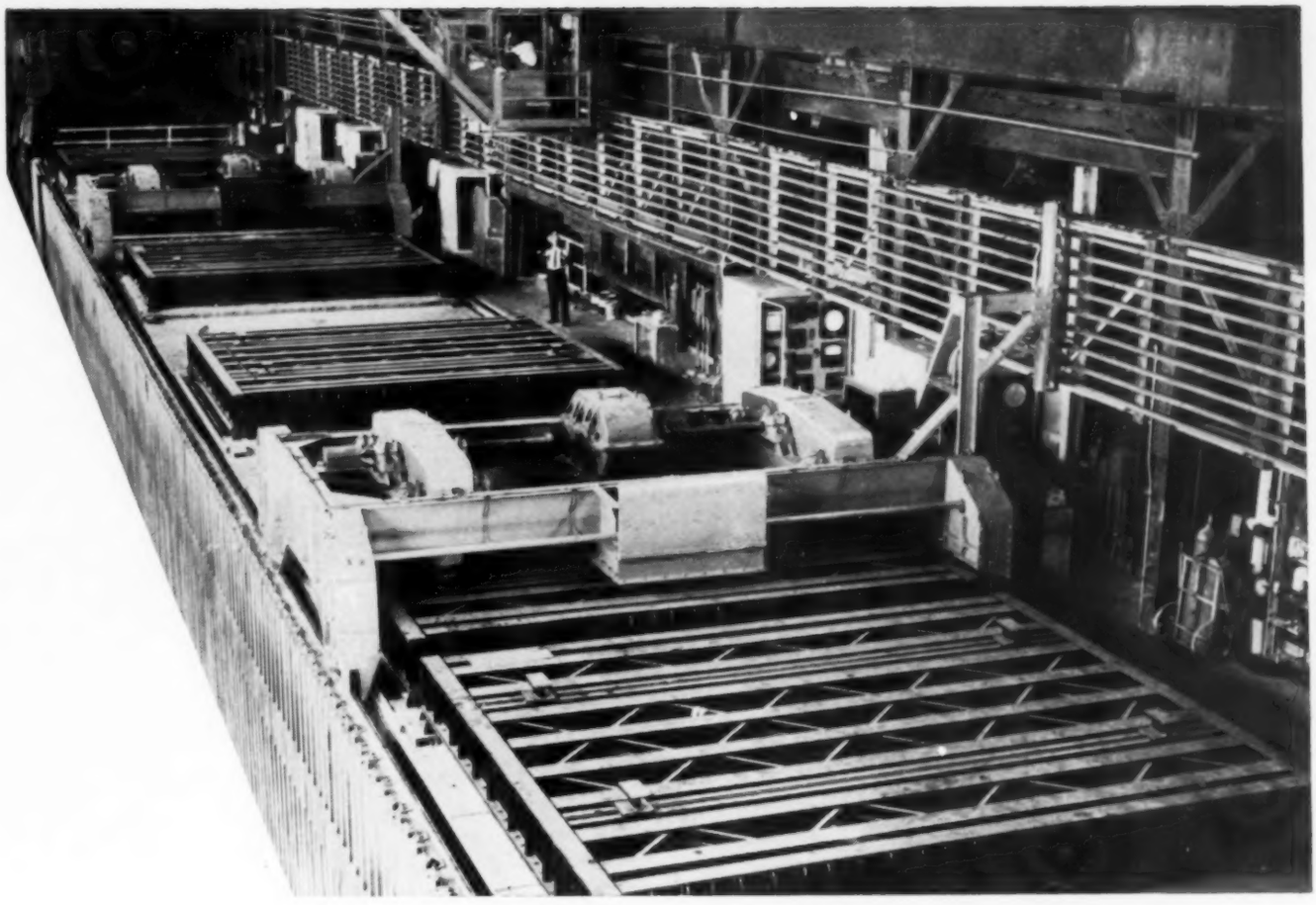

Soaking Pits by Amsler Morton, with L & N Integrated Control; for uniform heating of ingots at both bottoms and tops; for scale control; for no "washing"; minimum fuel; long refractory life; ability to hold ingots in condition until needed.

Integrated Control Helps Mills Get Well-Heated Steel

NEW FOLDER

Only 4 Pages — But Important to Cost-Conscious Executives!

WELL-HEATED STEEL — whether it's ingots, slabs, bars, blooms or forging stock — is steel at the right temperature, with the right surface, ready for processing at the right time. It's the kind of steel that the mill gets from good furnaces, operated by good men, with the best instrumentation to help.

Right now, when costs are high, here is welcome news about instrumentation which is helping to get well-heated steel *at lower cost*. This instrumentation is Integrated Control . . . L&N's newest means for regulating large furnaces.

An Integrated Control panel looks very much like any other panel for centralized automatic control, except that it includes an additional "key" instrument . . . the new L & N Fuel-Air Ratio Controller. This instrument adds to the panel a combustion control which matches your L&N Temperature Control in sensitivity and dependability; is designed specifically by L&N, to go with its companion L & N equipment. As a result, Integrated Control brings closer-stepping coordination between furnace atmosphere, uniform temperature and correct draft; it helps mills get well-heated steel by efficient, economical operation. For folder, write Leeds & Northrup Company.

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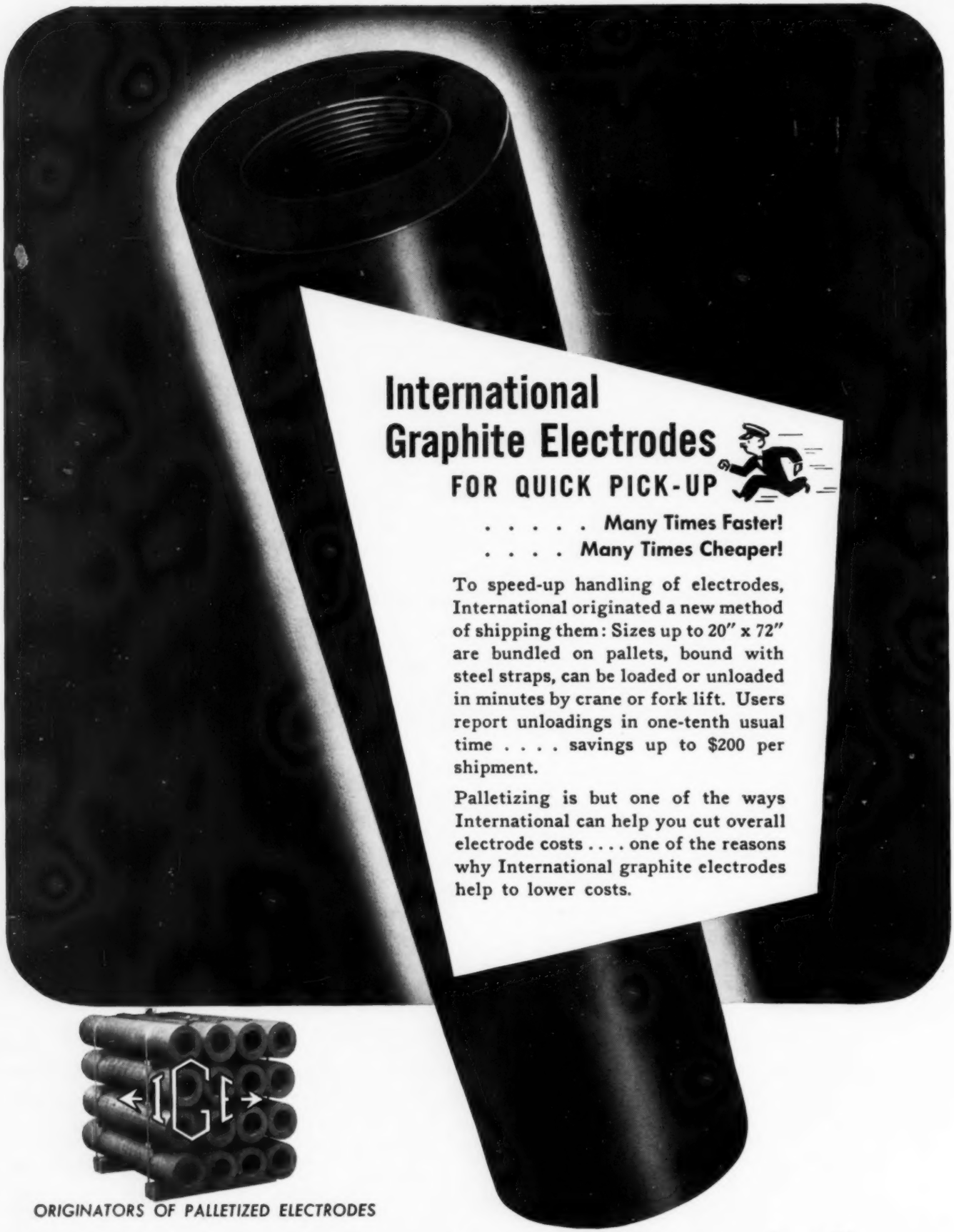
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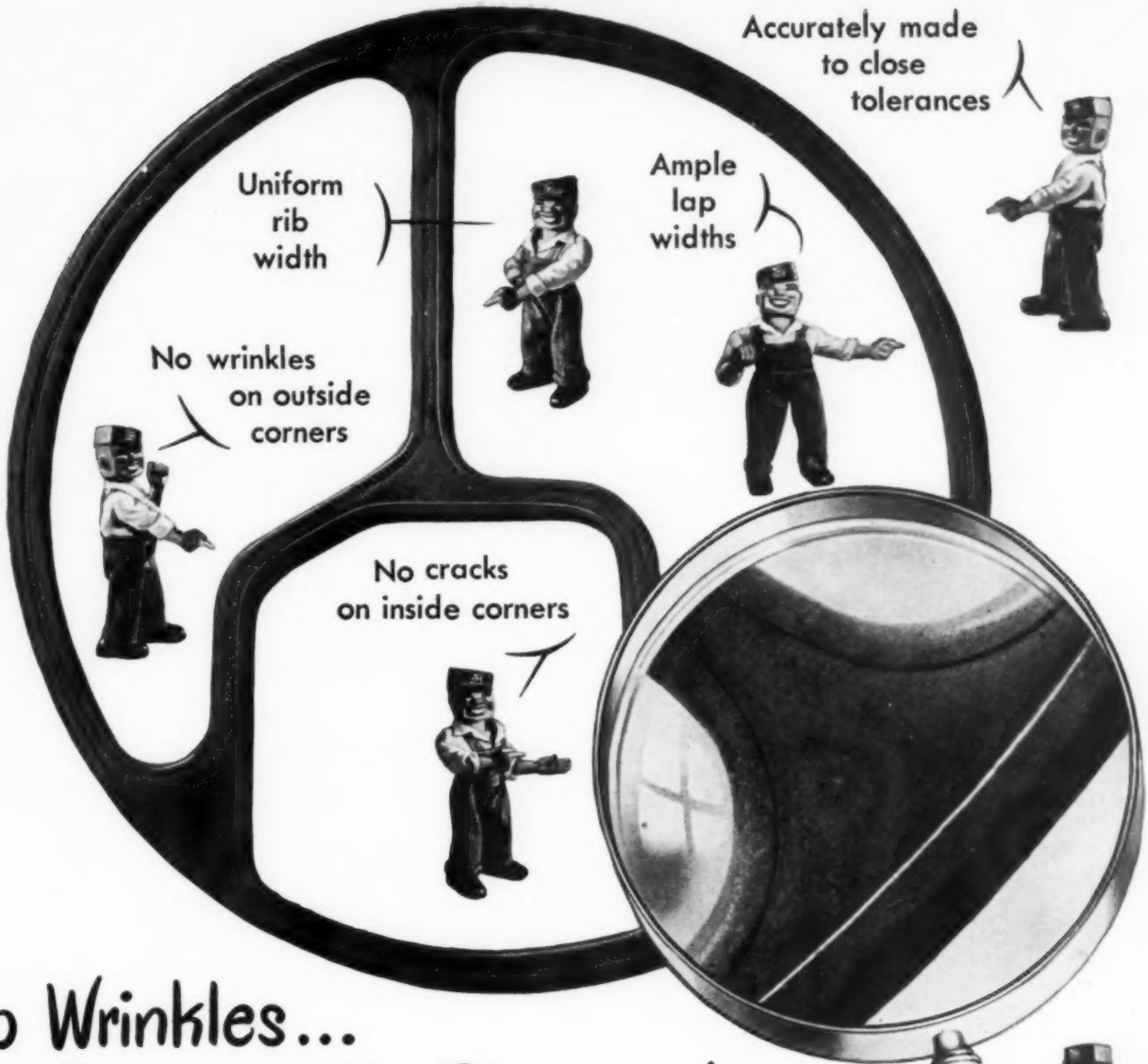
Accurately made to close tolerances
Uniform rib width
Ample lap widths
No wrinkles on outside corners
No cracks on inside corners

No Wrinkles... No Cracks... No Blowouts!

no place for leaks in THIS heat exchanger gasket

TAKE A CLOSE LOOK at the Goetze heat exchanger gasket shown above. Note the absence of wrinkles on outside corners . . . of cracks on inside corners . . . the uniform width of the ribs . . . the generous overlap of the metal jacket.

Attention to such important details is typical of the kind of care that goes into the forming of these custom-made gaskets. It is the secret of their dependable service—why you can count on them to stay on the job indefinitely without leaks or blowouts. And it's the reason they pay off in terms of less down-time and in the savings that result when gaskets *don't* have to be replaced at frequent intervals.

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You can have Goetze heat exchanger gaskets made in any size or shape. Estimates and recommendations will be furnished promptly on request. Write Johns-Manville, Box 290, New York 16, N. Y.

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Johns-Manville *Goetze* Gaskets

Shown here is a 250-ton push-pull, screw-type Stripper crane, used for stripping both small end-up ingots, and large end-up ingots with hot tops. An added feature for faster handling is the retractable bull nose; with this, no adjustments are necessary when stripping ingots of various types and sizes. Alliance builds this Stripper crane in various capacities up to 800 tons, with a safety factor of 5. If your installation does not warrant a stripper of this kind, ask us about our impact stripper, which makes use of the most reliable of all forces, gravity. The Alliance Machine Company builds all types—all sizes—to move heavy loads safely, quickly, economically. Always rely on Alliance to give your plant dependable, extra lifting power.

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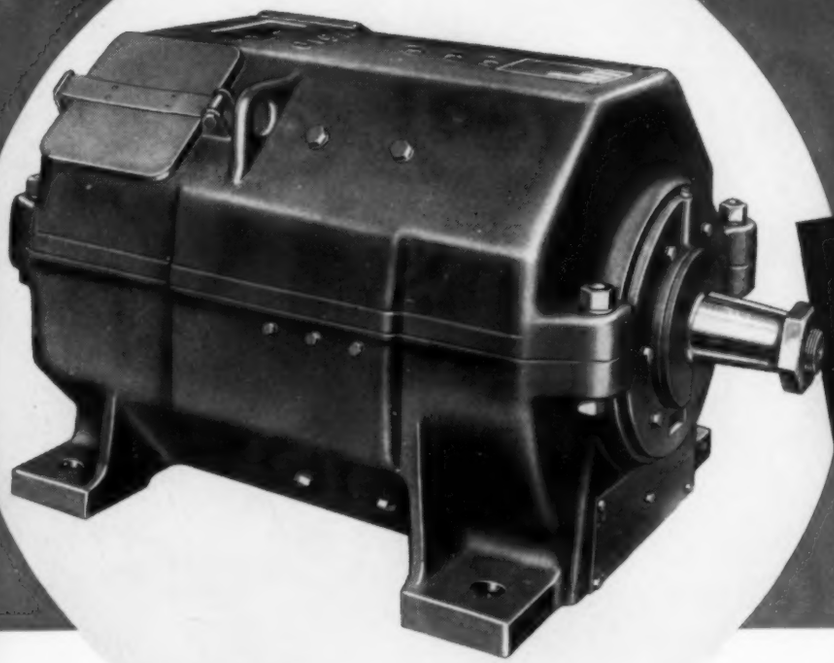
The New CROCKER-WHEELER FORM W 600 SERIES AUXILIARY MILL MOTOR

For Heavy Duty Mill and Crane Service



BUILT TO THE STEEL INDUSTRY'S SPECIFICATIONS!

Here's the mill motor the steel industry wanted. This new improved Form W 600 Series by Crocker-Wheeler is built to A.I.S.E. Standard No. 1. And it's available now!

More active material is provided in the same amount of space. Better utilization of existing space increases horsepower without adding to frame size.

Steel men said they wanted accessibility for motor servicing. Note, in the illustration above, how easy it is to get at all motor parts. And this is merely one of many new features Crocker-Wheeler has built into its new Form W 600 Series motors.

Crocker-Wheeler engineers are accredited specialists in building motors for cranes and heavy auxiliaries in steel mills. C-W designed the first mill type motor as far back as 1905, and has been making motor news in the steel industry ever since.

Find out more about the new Crocker-Wheeler Auxiliary Mill Motors—their greater efficiency, ease of maintenance and other unique advantages. Send today for Bulletin. Write Crocker-Wheeler Electric Mfg. Co., Ampere 3, N. J.

✓ CHECK THESE LOW MAINTENANCE — LONG-LIFE FEATURES

FIELD COILS Wound on mold over mica cell. Mica-washers at top and bottom of coil. Glass tape applied over cell, washers, and coil. Coil is filled layer by layer, during winding, with insulating compound that resists high temperatures, moisture, and oil, and provides an extremely homogeneous structure.

ARMATURE COILS Conductors are silicone-bonded, double-glass-covered wire. Slot portion of coil insulated with 4½ layers of glass-backed mica wrapper lapping with layers of glass-backed mica tape which extend around the coil bends and nose for reinforcement. Entire coil taped with closely woven glass tape.

INTERNAL CIRCULATION Integrally-cast fan blades on rear coil support circulate air through core ducts and between field coils, dissipating heat to frame. Provision is also made for forced ventilation.

GET COMPLETE DETAILS of these and many other reasons why the new Crocker-Wheeler Form W 600 series is your best buy in mill motors. Ask for Bulletin SL-620-1.

CROCKER WHEELER

ELECTRIC MANUFACTURING COMPANY, AMPERE 3, N. J.

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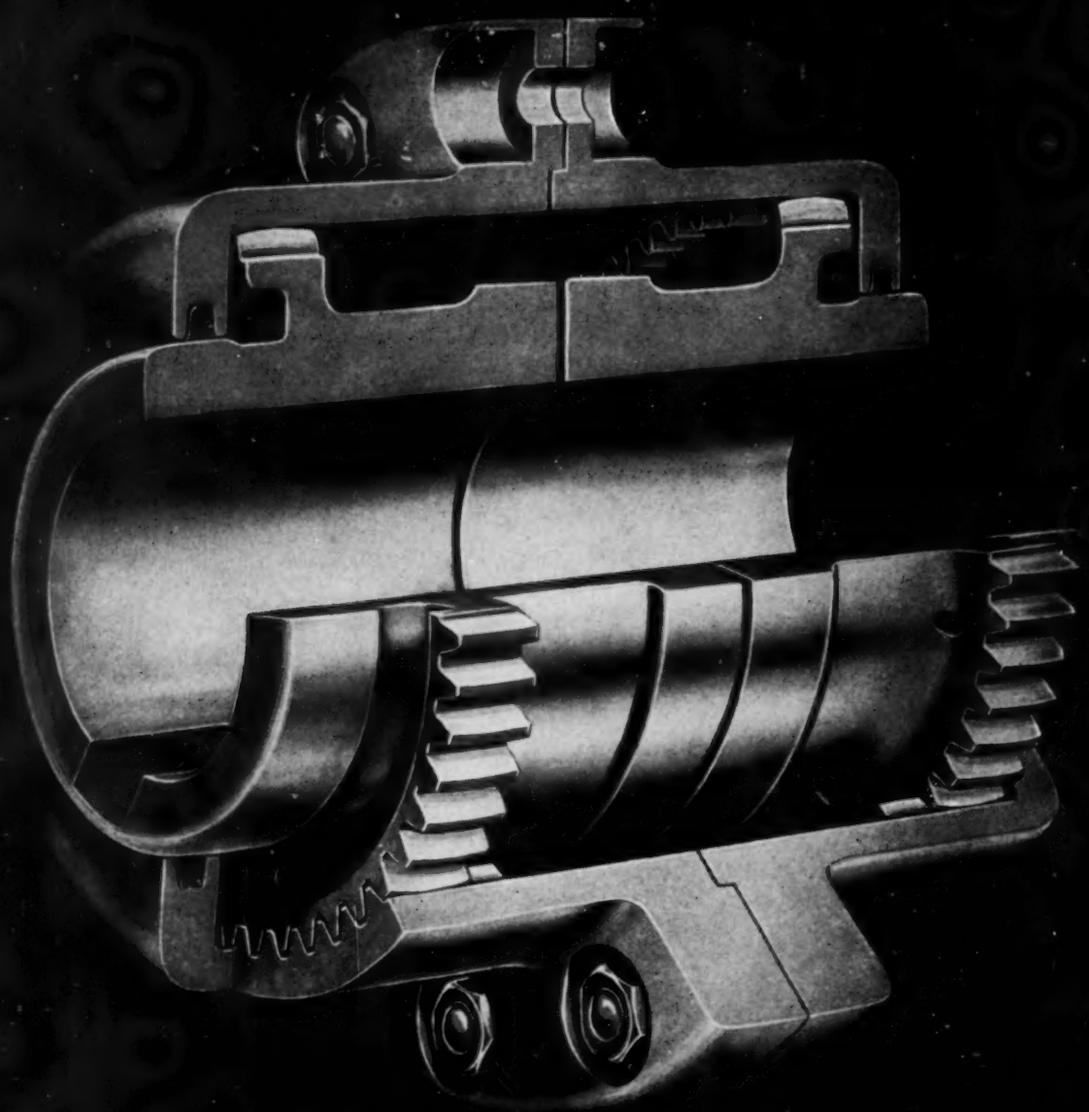
IF CROCKER-WHEELER BUILDS IT IT'S A BETTER BUILT MACHINE

POOLE



A COPY OF CATALOG GIVING FULL DESCRIPTION AND ENGINEERING DATA SENT UPON REQUEST.

FLEXIBLE COUPLINGS

POOLE FOUNDRY & MACHINE COMPANY

WOODBERRY, BALTIMORE, MD.

COLORADO FUEL AND IRON CORPORATION CHOSE

Eichleay

The new five-million dollar Rod Mill of the Colorado Fuel and Iron Corporation at Pueblo, Colorado marks the highest and most important achievement in the progress of steel wire making.

Eichleay was chosen to install the new-type Morgan Rod Mill which is the main feature of the plant, also the heavy cranes and all mechanical equipment, and to erect the structural steel which houses the mill.

Eichleay appreciates the honor of having been called upon for this service and of having been permitted to participate in the Pageant of Progress commemorating this important advancement in steel wire making.

Eichleay stands ready to furnish all industries the following services—

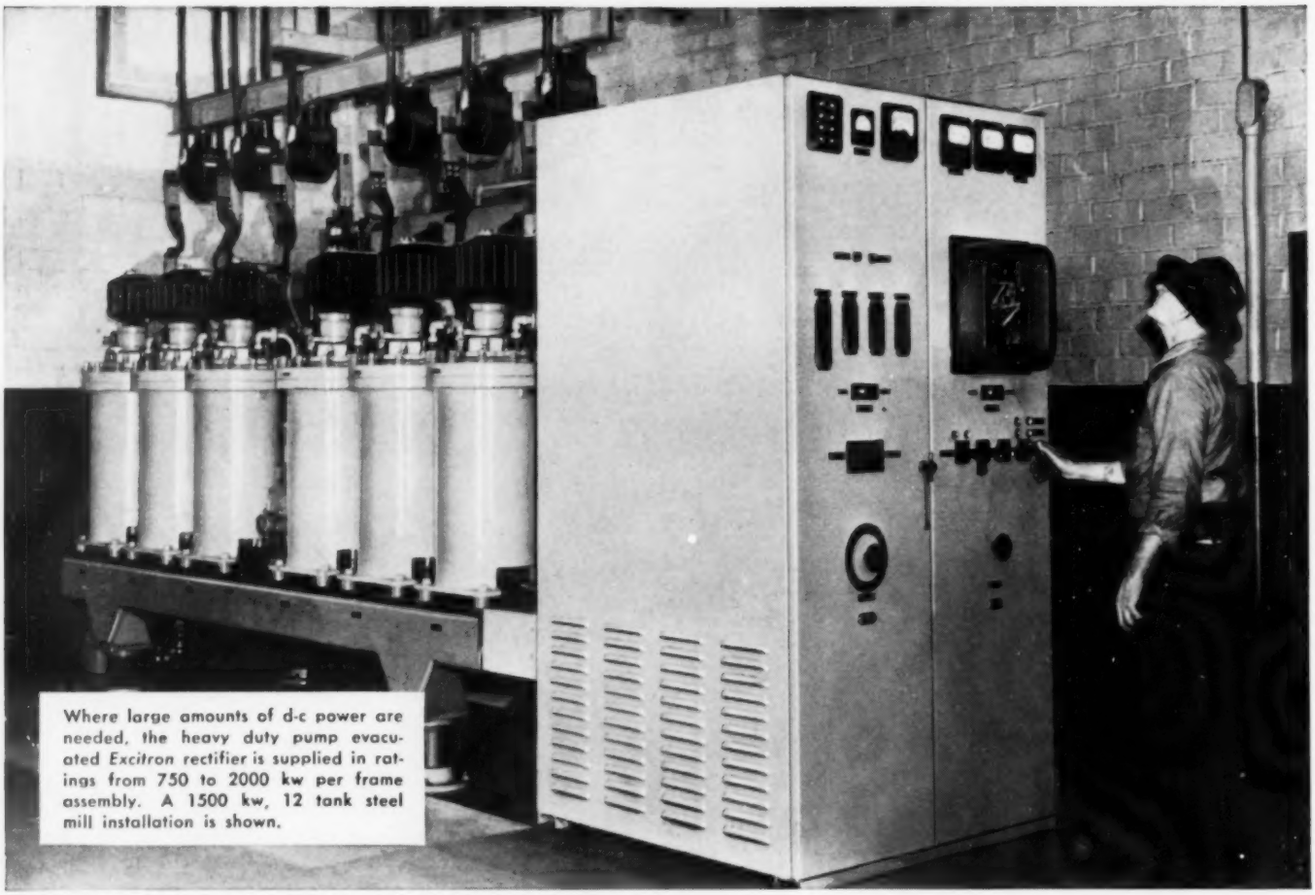
Plant Erection, Installation of Machinery, Relocation of Industrial Units, Construction of Foundations for Buildings and Equipment, Moving of Structures, Shoring, Rigging, Underpinning.

Write for your copy of the new illustrated booklet showing all types of erection, installations, etc.

EICHLEAY CORPORATION

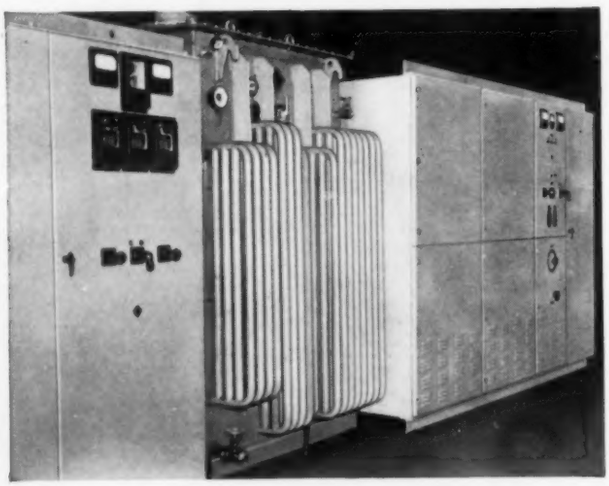
33 S. 19th STREET • PITTSBURGH 3, PA.

681 MARKET ST. • SAN FRANCISCO 5, CALIF.



Where large amounts of d-c power are needed, the heavy duty pump evacuated *Excitron* rectifier is supplied in ratings from 750 to 2000 kw per frame assembly. A 1500 kw, 12 tank steel mill installation is shown.

A-C Converts Power to D-C Right Where You Use It!



For smaller ratings and smaller load centers, Allis-Chalmers builds the sealed tube, factory assembled and packaged *Excitron* rectifier in ratings from 200 to 500 kw at 250 volts d-c.

TODAY'S COST IMPORTANCE is speeding the use of mercury arc rectifiers to supply general purpose 250 volt d-c power for steel mills. *Excitron* rectifiers can readily be placed right at the true d-c load center. Long, power-wasting d-c feeders are eliminated and voltage regulation and distribution efficiency are improved.

Excitron rectifiers are cheaper to operate and maintain than M-G sets. There are no problems of commutator and brush wear. No attendants are needed. Conversion efficiency is higher at all loads. Power savings are especially large where machine load factor is low and during long light load or idling periods.

A qualified Allis-Chalmers steel mill representative will be glad to further explain how *Excitron* rectifiers can benefit your operations. Call your nearest A-C sales office or write direct

A 2821

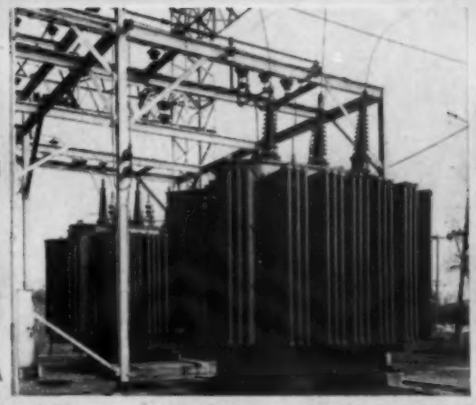
ALLIS-CHALMERS, 1020A SO. 70 ST.
MILWAUKEE, WIS.

Excitron is an Allis-Chalmers trademark.

ALLIS-CHALMERS

Power, Electric, Processing Equipment for Iron and Steel

2500 Kva, 3 phase, 13200Y-2400 Δ volts



10000 Kva, 3 phase, 66000 Δ-12470Y/7200 volts

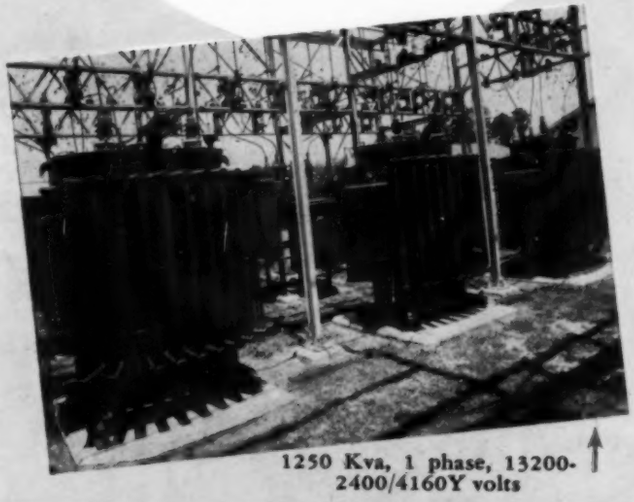
3750 Kva, 3 phase, 12000 Δ-2400 Δ/4160Y volts

1500 Kva, 3 phase, 12000 Δ-4330Y/2500 volts

Others are SAVING UP TO 8% on their POWER TRANSFORMERS

So can you by specifying

PENNSYLVANIA STANDARD PARTS POWER TRANSFORMERS



1250 Kva, 1 phase, 13200-2400/4160Y volts

Here are some Standard Parts Power Transformers that have been manufactured in the Pennsylvania Plant and delivered to Utilities and Industrials in various parts of the country.

Because these are Standard Parts Transformers, they were purchased at considerable discounts — up to 8%.

It will pay you to find out about the PENNSYLVANIA Standard Parts Power Transformers and why they can be bought for less. We invite you to write for more information.

Pennsylvania

TRANSFORMER COMPANY

Canonsburg, Pennsylvania

Greater Pittsburgh District

mail this coupon

PENNSYLVANIA TRANSFORMER COMPANY
Box 330, Canonsburg, Pa.

Please send me a copy of your Standard Parts Power Transformer Bulletin No. 1492.

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Company _____

Street _____

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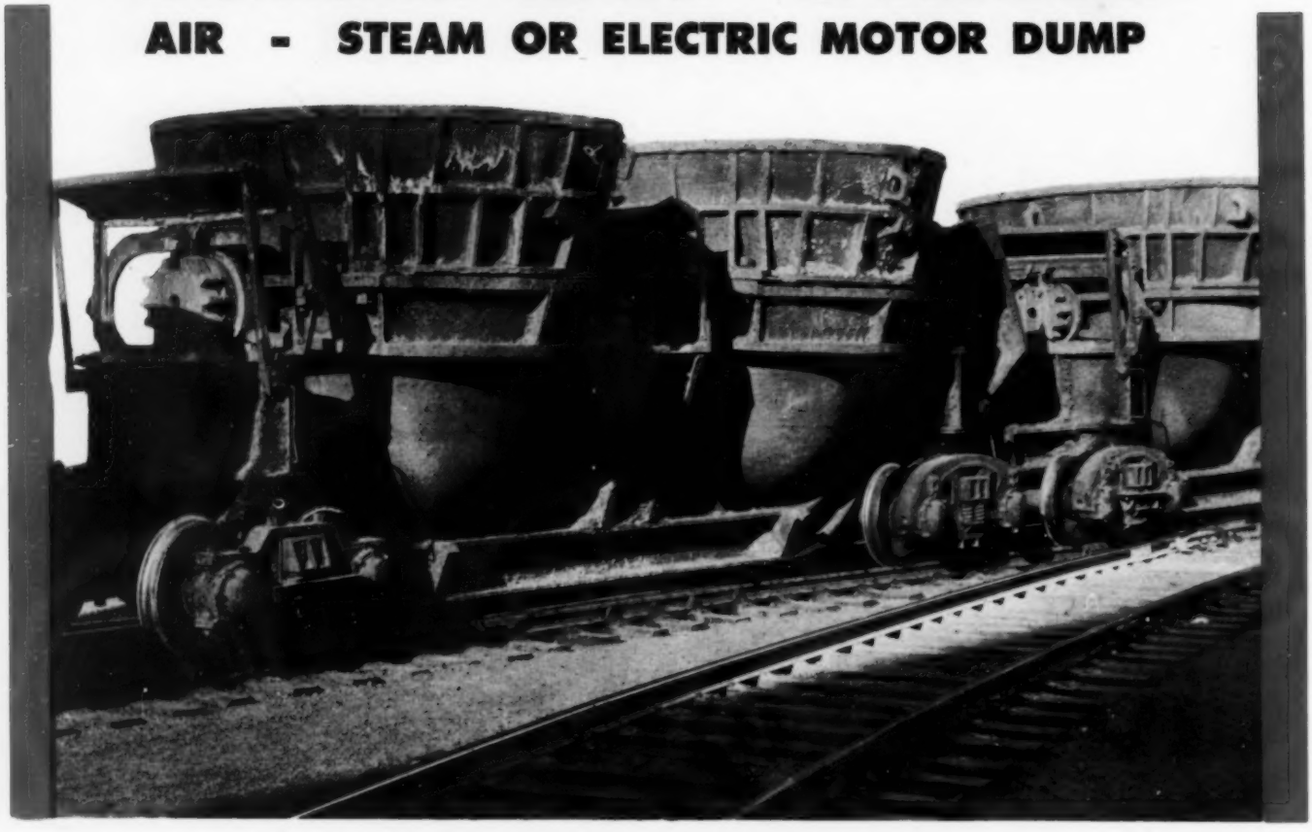
TREADWELL

CINDER CARS

AIR - STEAM OR ELECTRIC MOTOR DUMP



800 CUBIC FOOT TWIN POT CAR

Increased Blast Furnace Capacity

REQUIRES

Additional Cinder Handling Equipment

TWIN POT CARS will enable you to HANDLE 20% MORE SLAG on the same track length

M. H. TREADWELL CO., INC.

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CHICAGO 4, ILL.
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1217 FARMERS BANK BLDG.
PITTSBURGH 22, PA.
ATlantic 1-6[illegible]

HEAD: WRIGHTSON AND CO., LTD., Thornaby on Tees, England

B&W IFB help anneal tank cars, too!

To anneal welded railroad tank car bodies and other products, a wide heat range, with extreme flexibility to meet complicated heat treating problems, was an important requirement in this large furnace designed and built by **JET COMBUSTION, INC.** for General American Transportation Corporation.

B&W IFB — which have the lightest weight, lowest heat loss, and the lowest heat storage of all insulating firebrick — were selected for the furnace lining.

These qualities of B&W Insulating Firebrick assure quick temperature control and rapid response to changes in heat input. Then, too, their extra light weight saves on furnace construction costs, simplifies furnace design.

Whether your furnace is large or small, you will benefit by using economical B&W Refractories. Why not talk it over with your local B&W Refractories Engineer. Just telephone or drop him a postcard today.

FURNACE SPECIFICATIONS

Inside length	52'
Inside width	19'
Car top to arch	21'
Arch Span	21'

Walls of B&W K-23 IFB
Arch of B&W K-26 IFB

R-359

B&W REFRACTORIES PRODUCTS

B&W 80 FIREBRICK • B&W JUNIOR FIREBRICK
B&W 80 GLASS TANK BLOCKS • B&W INSULATING FIREBRICK
B&W REFRACTORY CASTABLES, PLASTICS AND MORTARS

•

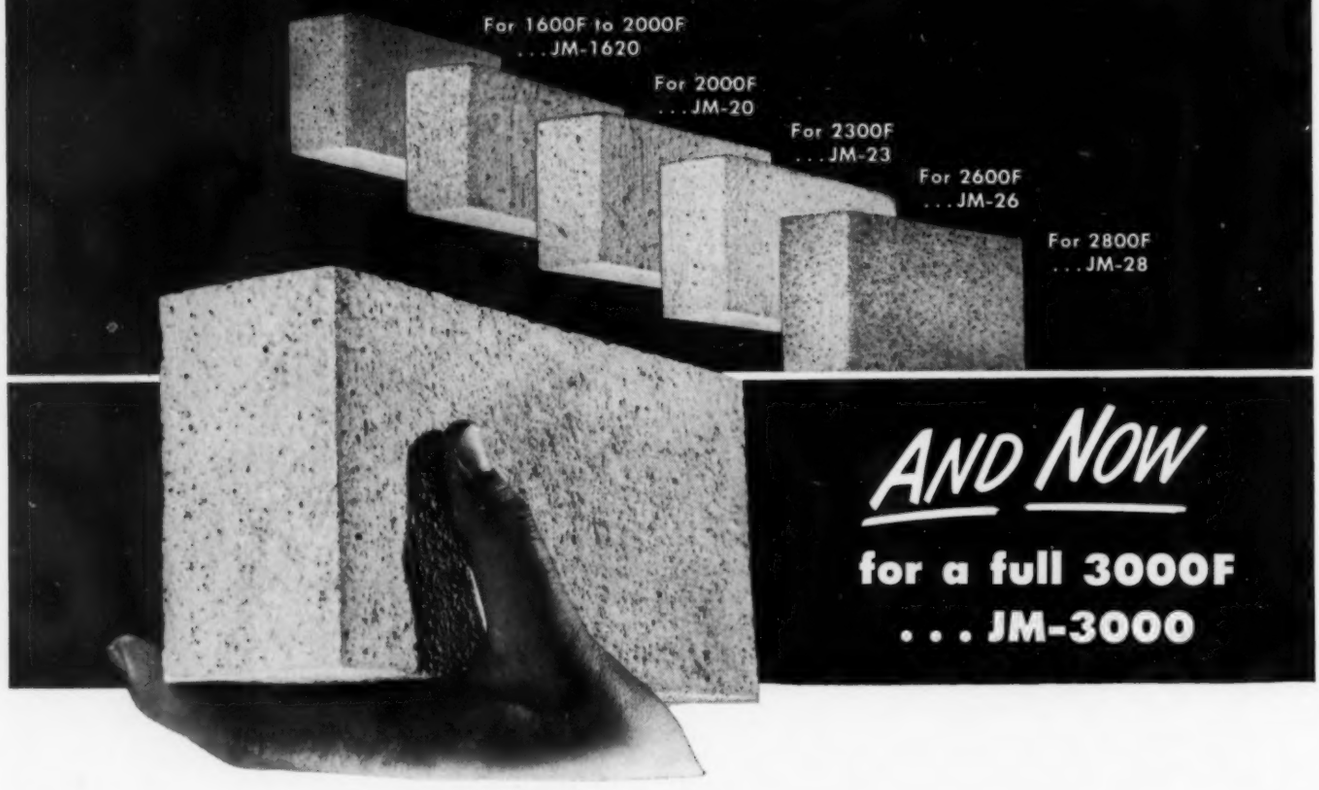
OTHER B&W PRODUCTS

Stationary & Marine Boilers and Component Equipment
Chemical Recovery Units . . . Seamless & Welded Tubes . . . Pulverizers
Fuel Burning Equipment . . . Pressure Vessels . . . Alloy Castings

BABCOCK & WILCOX

THE BABCOCK & WILCOX CO.
REFRACTORIES DIVISION
GENERAL OFFICES: 85 LIBERTY ST., NEW YORK 6, N.Y.
WORKS: AUGUSTA, GA.

MEET the family of Johns-Manville Insulating Fire Brick . .



HERE IS AN OUTSTANDING FAMILY of insulating fire brick for back-up or exposed use . . . the only family of its kind . . . that gives you a complete range . . . a *quick heating* insulating fire brick for every purpose.

By taking advantage of the quick heating characteristics of these insulating fire brick, you'll benefit through important savings in fuel because of the quicker rise to proper operating temperature in the furnace. This is a result of the low heat storage capacity and low thermal conductivity characteristics of the brick. These factors are especially important where furnaces are being intermittently operated.

The same materials can also be obtained in large size units as Johns-Manville Insulating Fireblok. This product has many advantages over the smaller size fire brick, from both a construction and stability standpoint. They can be quickly applied because they are easy to cut and fit. J-M Insulating Fireblok provide additional heat savings because they reduce the number of joints, and require less mortar for bonding.

Why not have a Johns-Manville insulation expert call to tell you more about ways in which you can save by using these insulations in your furnaces. Write Johns-Manville, Box 290, New York 16, N. Y. for further information.

	JM-1620	JM-20	JM-23	JM-26	JM-28	JM-3000
Densities, lb per cu ft	29	35	42	48	58	63-67
Transverse Strengths, psi	60	80	120	125	120	200
Cold Crushing Strengths, psi	70	115	170	190	150	400
Linear Shrinkage,† percent	0.0 at 2000 F	0.0 at 2000 F	0.3 at 2300 F	1.0 at 2600 F	4.0 at 2800 F	0.8 at 3000 F
Reversible Thermal Expansion, percent	0.5—0.6 at 2000 F	0.5—0.6 at 2000 F	0.5—0.6 at 2000 F	0.5—0.6 at 2000 F	0.5—0.6 at 2000 F	0.5—0.6 at 2000 F
Conductivity* at Mean Temperatures						
500 F	0.77	0.97	1.51	1.92	2.00	3.10
1000 F	1.02	1.22	1.91	2.22	2.50	3.20
1500 F	1.27	1.47	2.31	2.52	3.00	3.35
2000 F	—	1.72	2.70	2.82	3.50	3.60
Recommended Service						
Back up	2000 F	2000 F	2300 F	2600 F	2800 F	3000 F
Exposed	1600 F	2000 F	2300 F	2600 F	2800 F	3000 F

† *24-hr simulative service panel test for JM-3000; 24-hr soaking period for other brick.*

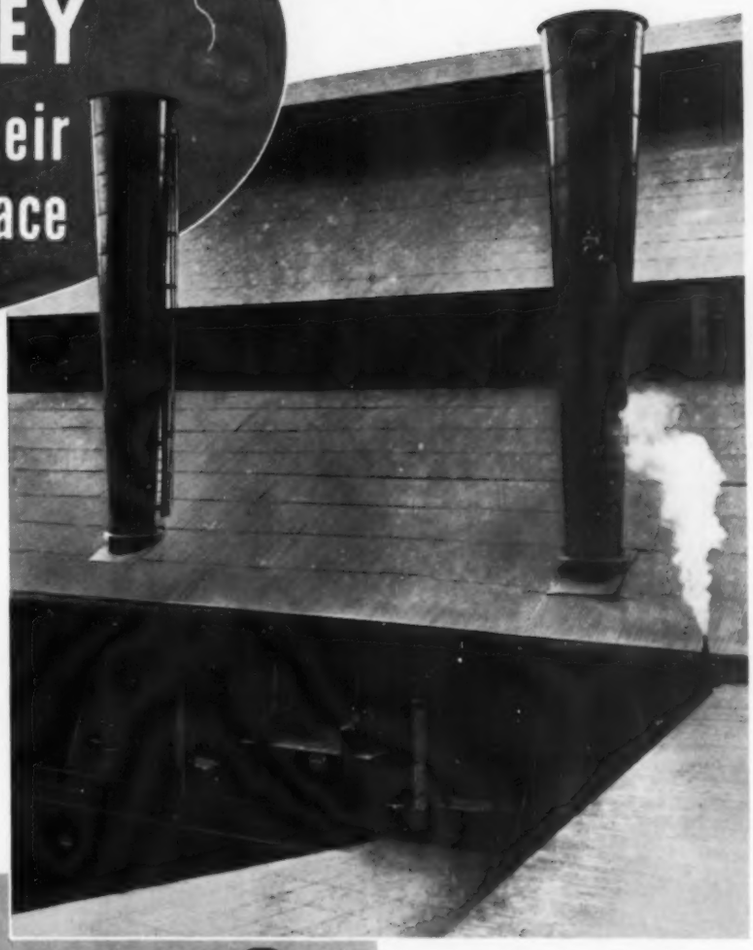
* *Conductivity is expressed in Btu in. per sq ft per F per hour at the designated mean temperatures.*

Note: Above tests are in accordance with A.S.T.M. tentative standards.

JOHNS-MANVILLE JM PRODUCTS

Johns-Manville First in INSULATIONS

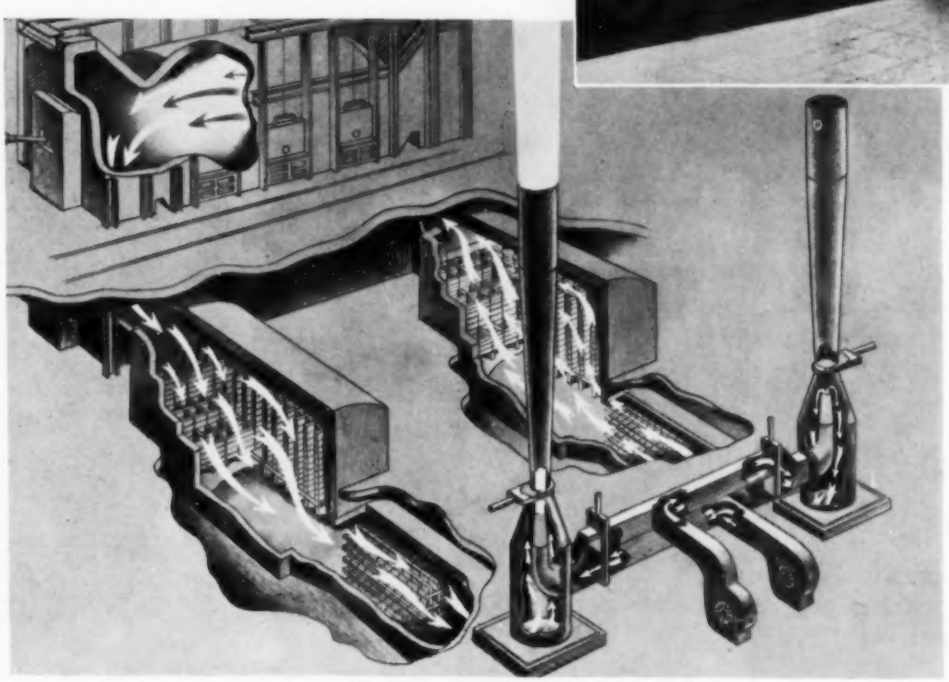
Weirton selects MORGAN-ISLEY CONTROL for their new 550-ton furnace



The certainty of Morgan-Isley Control over the uncertainty of natural draft is one of the impelling reasons behind its increasing popularity.

Increased flame temperature and greater recovery of waste heat result in more tonnage and lower fuel rates.

Our new bulletin explains the many advantages of the Morgan-Isley System over natural draft. Send for your copy today.



View of the diffusers and double duct system of the Morgan-Isley control installed at the new Weirton 550-ton furnace.

MORGAN CONSTRUCTION COMPANY WORCESTER, MASSACHUSETTS

CCC-23

DEPENDABLE POWER

BAKER FORK TRUCK

BAKER HIGH LIFT PLATFORM TRUCK

Battery Electric Trucks and
EXIDE-IRONCLAD BATTERIES
CUT COSTS ALL ALONG THE LINE

With battery electric trucks in your plant, materials will move faster, smoother, safer, easier . . . and at a BIG saving—often as much as 50% or more. When powered by Exide-Ironclad Batteries, you can count on full shift availability with minimum power and replacement costs.

The EXCLUSIVE positive plate makes Exide-Ironclad Batteries DIFFERENT

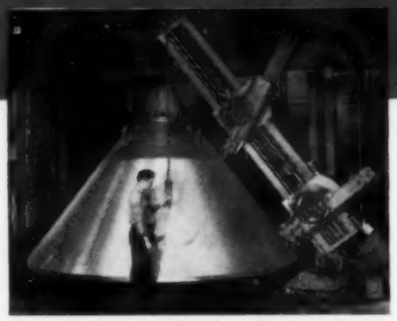
They differ not only in construction, but also in performance and length of service life. Exide-Ironclad Batteries have ALL FOUR of the essential characteristics that a storage battery must have to assure maximum performance from battery electric trucks—high power ability, high electrical efficiency, ruggedness and a long life with minimum maintenance. The combination of these four Exide-Ironclad characteristics assures years of day-in, day-out service with dependability and economy.

Write for further particulars and FREE copy of Exide-Ironclad Topics, which contains latest developments in materials handling and shows actual case histories.

1888...DEPENDABLE BATTERIES FOR 61 YEARS...1949

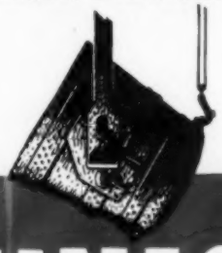
"Exide-Ironclad" *Reg. Trade-mark U. S. Pat. Off.*

THE ELECTRIC STORAGE BATTERY COMPANY, Philadelphia 32 • *Exide Batteries of Canada, Limited, Toronto*



Turning a 48,610 lb. Blast Furnace Bell in our completely equipped machine shops.

"Union" Ingot and Charging Box Cars go a long way to make friends and save money.



When other pots wear out "UNION'S" wear on and on

Slag and cinder pots are the indispensable "garbage cans" of the Steel Industry . . . They cost money yet produce nothing. So the ones that cost you less per day —less per ton handled—are the cheapest by far.

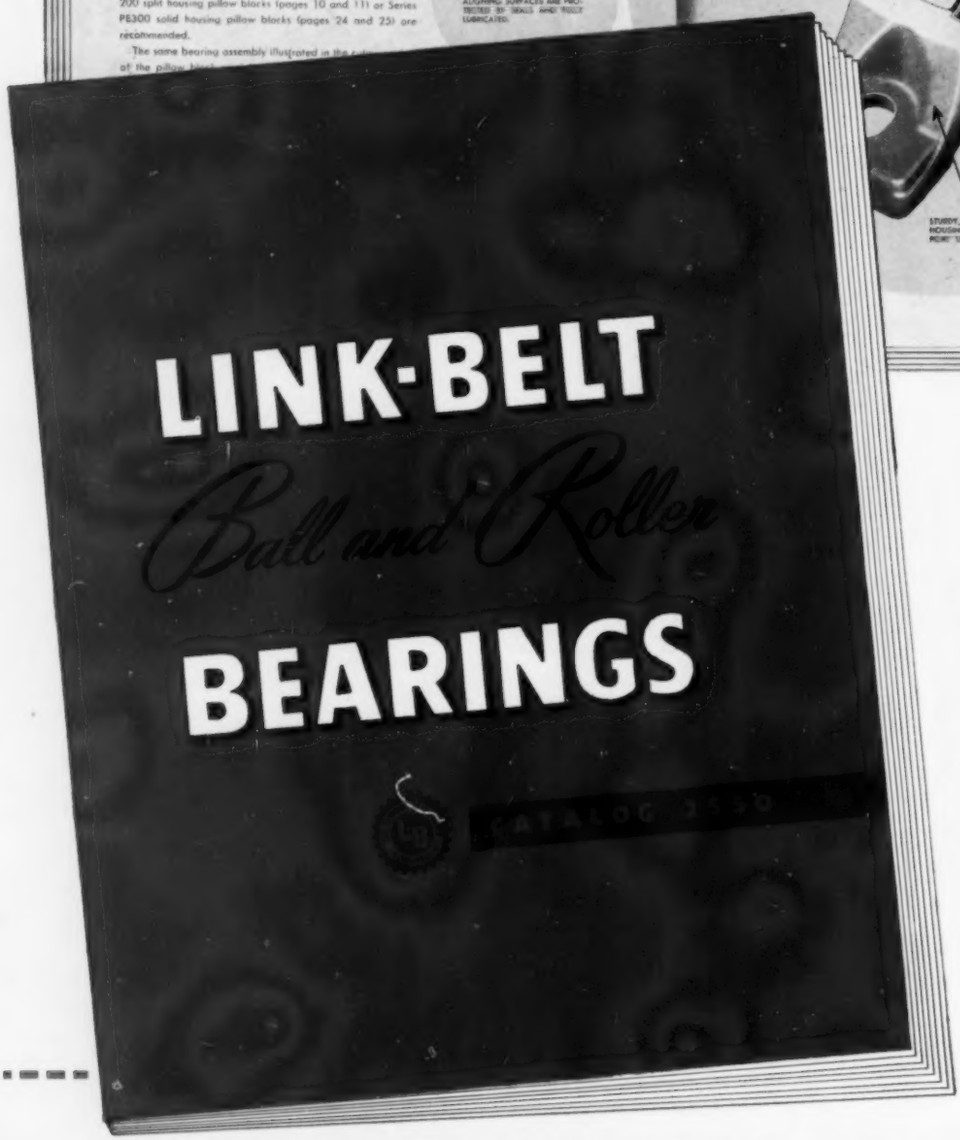
As far as size and shape go, "Union" Pots are built to your specifications. But the choice of metal, the method of manufacture, the even wall thickness and smooth inside finish are exclusively "Union's" . . . Glad to quote on your requirements for pots that wear on where others wear out.

UNION STEEL CASTINGS

DIVISION OF BLAW-KNOX COMPANY . . . PITTSBURGH 22, PA.

YOUR COPY is Ready!

Series 200 ball bearing pillow blocks • solid housing
Series 200 solid housing pillow blocks are equipped with self-aligning, single raw deep groove ball bearings having as basic design the standards for "AFBMA series BC02 ball bearings, and are available for shaft sizes from 5/8" to 3-15/16" (maximum recommended speed range from 8500 to 2000 RPM).
They are designed for grease lubrication only. If oil lubrication is essential, Series LP200 split housing pillow blocks (pages 10 and 111) are recommended.
Where axial shaft float of bearing is required, Series LP-200 split housing pillow blocks (pages 10 and 111) or Series PB300 solid housing pillow blocks (pages 24 and 25) are recommended.
OUTSTANDING FEATURES
Series 200
LUBRICANT PASSES FREELY BETWEEN THE SEAL AND OUTER RING INTO RESERVOIR TO LUBRICATE BEARING AND ALIGNING SURFACES. LARGE RESERVOIR PROVIDES LUBRICATION INTERVALS.
EASILY INSTALLED BY SIMPLY SLIPPING INNER RING ONTO SHAFT AND LOCKING IN POSITION.
LINK-BELT - 9



112 PAGES

OF DESCRIPTIVE AND ENGINEERING DATA ON THE COMPLETE LINE OF MOUNTED AND UNMOUNTED LINK-BELT BALL AND ROLLER BEARINGS. . . .

IF YOU USE BEARINGS, YOU SHOULD HAVE THIS NEW CATALOG!

Send for YOUR COPY . . . today!

11,624

LINK-BELT COMPANY, 519 N. Holmes Ave., Indianapolis 6, Indiana
(or your nearest Link-Belt office or Link-Belt bearing distributor): Please send Catalog 2550.

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For modern Roll types . . .

LEWIS ROLLS

OVER 90 YEARS OF ROLL MAKING

LEWIS PLAIN CHILLED IRON ROLLS

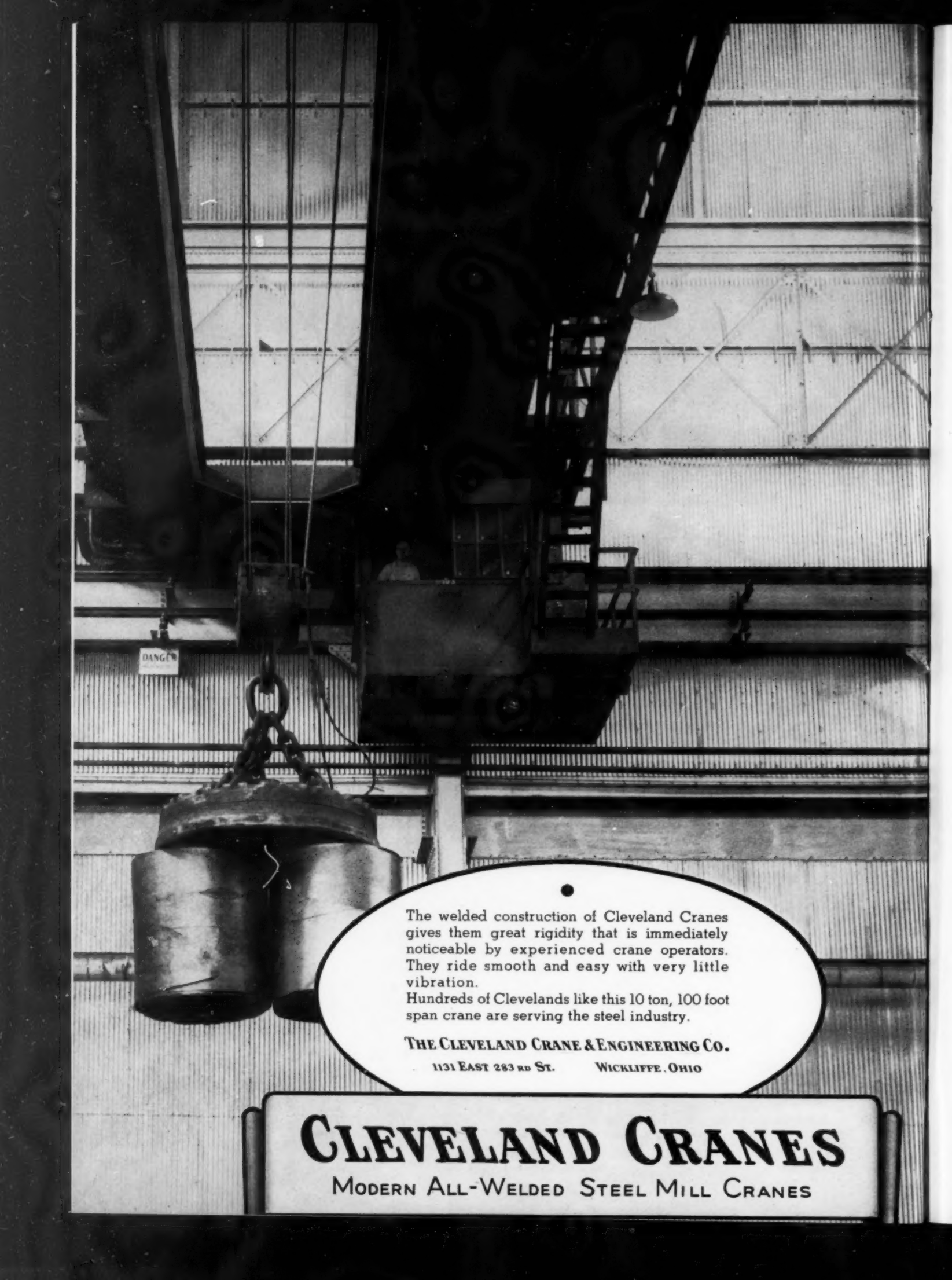
LEWIS MOLYBDENUM CHILLED IRON ROLLS **LEWIS "X" and LEWIS "XA" ROLLS** (Alloy Grain Type) **LEWIS SUPERIOR "X" ROLLS** (Nickel Grain Type)

LEWIS ATLAS and ATLAS "B" ROLLS (Alloy Grain Type) **LEWIS SPECIAL PROCESS ROLLS** (Chill and Grain Type) **LEWIS AJAX DUPLEX ROLLS** (High Alloy Grain Type) **LEWIS CLIMAX and AJAX ROLLS** (High Alloy Grain Type) **LEWIS SPECIAL TUBE MILL ROLL**

MAY WE HAVE THE OPPORTUNITY OF STUDYING YOUR REQUIREMENTS AND SUBMITTING OUR RECOMMENDATIONS

MANUFACTURERS OF ROLLS AND ROLLING MILL MACHINERY FOR THE IRON, STEEL AND NON-FERROUS INDUSTRIES

LEWIS FOUNDRY AND MACHINE DIVISION
OF BLAW-KNOX COMPANY · PITTSBURGH, PA.



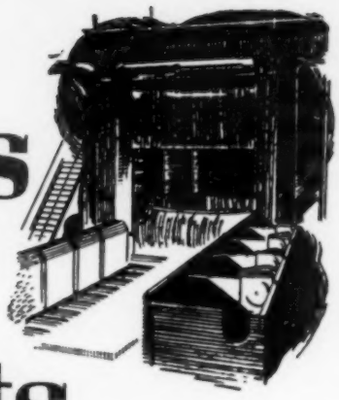
The welded construction of Cleveland Cranes gives them great rigidity that is immediately noticeable by experienced crane operators. They ride smooth and easy with very little vibration.
Hundreds of Clevelands like this 10 ton, 100 foot span crane are serving the steel industry.

THE CLEVELAND CRANE & ENGINEERING CO.
1131 EAST 283 RD ST. WICKLIFFE, OHIO

CLEVELAND CRANES

MODERN ALL-WELDED STEEL MILL CRANES

Crops and Shorts



SETTLEMENT of the steel strike upon the so-called "Bethlehem plan" has been hailed by Philip Murray as a great victory for labor. Supposedly, it will provide "security." That's a nice word — one that appeals to everyone. But let's look a little closer.

By ignoring the recommendation of the Fact Finding Board that each company's ability to pay be considered, and by insisting that terms of settlement be uniform for all companies, Mr. Murray has put many companies in precarious positions. Some small companies may disappear and some marginal plants may operate only spasmodically. Is this security for the employees of these plants?

Actually, the cost of the new plans cannot be readily determined as yet. Since all pensions to be paid by the companies are reducible by the amount the employee is entitled to receive under Federal Social Security, any increase in the latter, as is now under consideration, will reduce the companies' obligation. Also, companies who already had some type of pension plan may not be called on to pay out much, if anything, more. But suppose the costs do necessitate an increase in the price of steel. This may touch off increases in other lines, and lead us further into inflation. Is this security?

Many of the industrialists who were accused of reactionary stubbornness because of their opposition to non-contributory pensions actually maintained their position because of the fear that this plan might be impossible to maintain through varying business conditions of the future. The new pensions are not funded or backed up in accordance with actuarial principles, which would require more than the total value of the industry. Hence they must be carried out of current profits — a liability, if you please, upon those who have not yet retired. If it cannot be kept up at all times, many of those who are planning on it will suffer bitter disappointment. Is this security?

Under the new plans, employees who move from one company to another lose all their pension rights. New industries may have trouble in obtaining workers. The urge to retain the stake they have built up in their future security may lead workers to pass up fine opportunities in other companies. This may be security, but only at the price of freedom and possible betterment.

The desire for "security" — and the lure of the wishful idea of getting something for nothing — has led to a crazy-quilt of federal, state, industrial, union, fraternal, and even regional pensions with millions of individuals still not covered in any way. Some industrialists have already come out for adequate federal pensions to replace the hodge-podge, and U. S. Senator Robert Taft has suggested thorough study of the feasibility of $100 monthly pensions for everyone at age 65. The cost is estimated at $12,000,000,000 or more per year, and Senator Taft states that this drain might deter business and industry, and lower the workers' standard of living. Is this security?

▲

A MAN who gives in when he is wrong is wise. A man who gives in when he is right is married.

▲

ADDRESSING the recent joint meeting of the Eastern States and the Chicago District Blast Furnace and Coke Oven Associations, R. E. Roberts, manager of employee relations for Ford Motor Company, stated:

"Business has been so involved with other problems that it has made too little effort to communicate its own thinking to the men and women who have an equally vital stake in our business and industrial life. In other words, it has not succeeded in keeping its employees informed properly of its policies and problems, and of the reasons and purposes which lie behind its actions. It has failed to help all members of the business and industrial family to understand the factors which shape and direct our economic life.

As a result, our workers have turned to other sources for their information. They have drawn their economic knowledge from material that is not always reliable or complete in all the details of an issue. If we were to examine those sources, we would too often find that the whole story is not told, that statistics are misrepresented and that management's aims and policies are distorted.

It is not surprising, under the circumstances, that some workers are misled into believing that all companies are hostile to the interests of their employees or that all companies can pay higher wages and pensions because they all make huge profits.

Management has a responsibility to so keep its employees informed that we may... help create a better understanding of the problems of industry in the minds of employees and their families."

▲

WE shouldn't expect too much from any set of rules. Look how long it is taking to put across the ones Moses gave us.

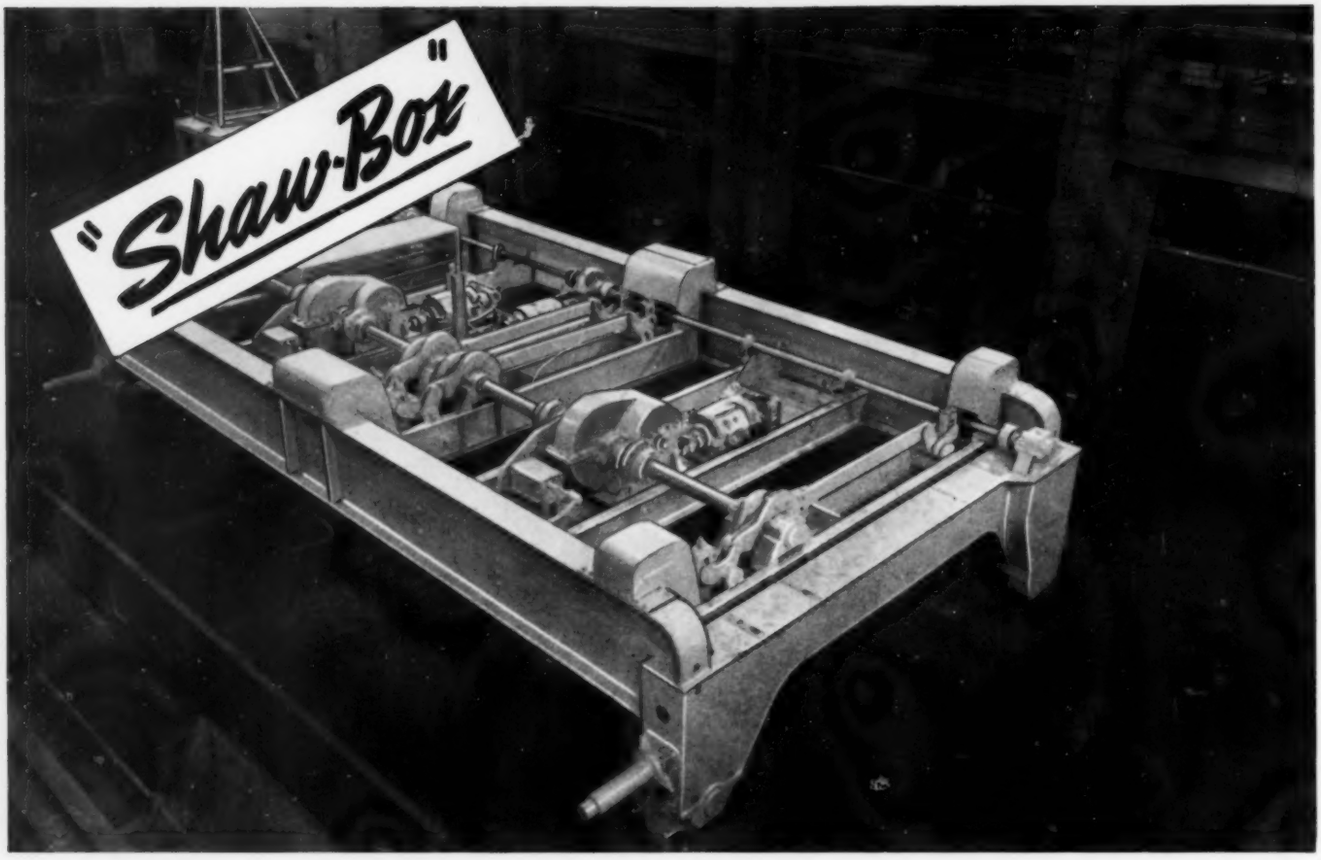
▲

FROM a speech by W. Walter Williams, chairman of the Committee for Economic Development and president of Continental, Inc.: "In my opinion, five principles from the economic foundation of constructive collective bargaining:

1. Labor and management must believe in capitalism and help to make it work.
2. Labor and management must believe in ever-increasing productivity, and must work to achieve it.
3. Labor and management must believe in the importance of the managerial function.
4. Labor and management must make decisions on the basis of economic fact, not economic power.
5. Labor and management must accept their primary responsibility to the community."

▲

EDUCATION is generally expensive, but ignorance costs more.



SOAKING PIT CARRIAGES

When your Soaking Pit Carriages are "Shaw-Box," you get dependable, economical service under the most severe operating conditions.

Soaking Pit Carriages are a "Shaw-Box" specialty, ruggedly built to exacting standards of fine engineering and workmanship. Exclusive patented "Shaw-Box" construction features result in smoother operation, reduced impacts on carriages, pits and covers, and lower maintenance. These important advantages result from lifting with eccentrics instead of the ordinary hydraulic cylinder or crank mechanism; spherical bearings on top and bottom of hangers allow lifting beams to "thread" into lifting tees; traverse motor and cross shaft mounted inside girder gives utmost protection to the driving mechanism; and a system of interlocks provides maximum safety.

"Shaw-Box" Soaking Pit Carriages are built to give you real performance with a minimum of attention.

Be sure to send all your inquiries and specifications for Soaking Pit Carriages and Steel Mill Cranes to "Shaw-Box."

MANNING, MAXWELL & MOORE, INC.
SHAW-BOX CRANE & HOIST DIVISION
MUSKEGON, MICHIGAN

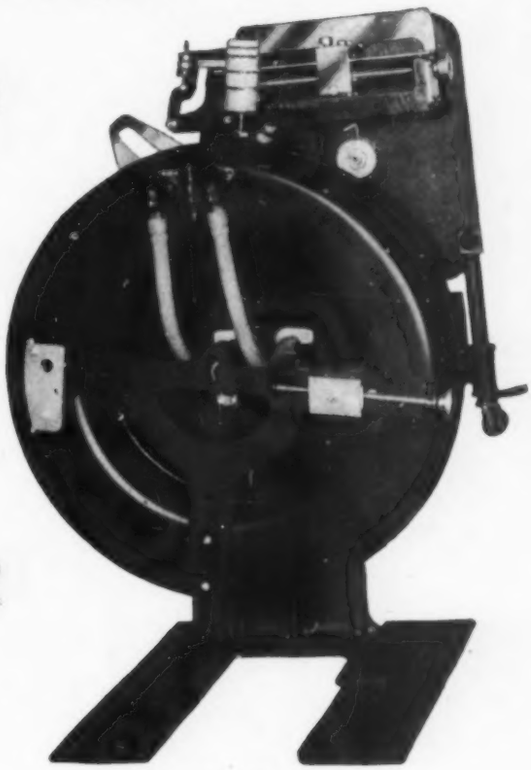
Builders of "Shaw-Box" Cranes, 'Budgit' and 'Load Lifter' Hoists and other lifting specialties. Makers of 'Ashcroft' Gauges, 'Hancock' Valves, 'Consolidated' Safety and Relief Valves, 'American' Industrial and 'Microsen' Electrical Instruments.

A differential of ½ inch of water gives full scale operation with this

HAGAN

Ring Balance

FLOW METER



MODEL 2256 WITH
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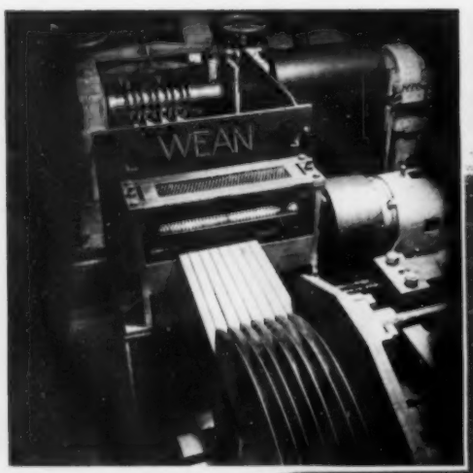

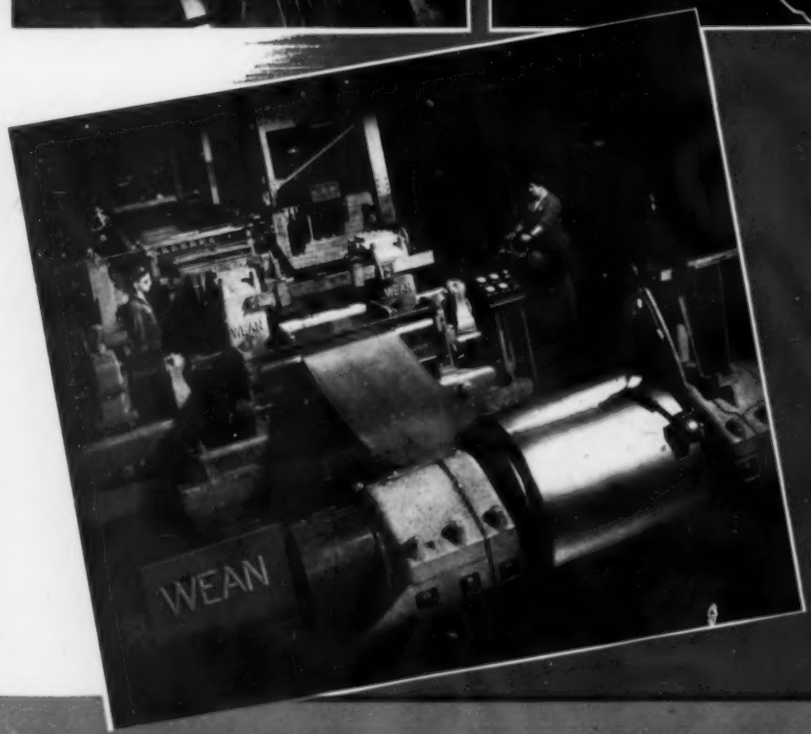

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Iron and Steel ENGINEER

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STRESSES IN HOT METAL LADLES

By K. E. KNUDSEN, WM. H. MUNSE and B. G. JOHNSTON
Fritz Engineering Laboratory
Lehigh University
Bethlehem, Pa.

. . . .this report describes the results of a research investigation sponsored and financed by the Association of Iron and Steel Engineers for the steel industry . . . .

▲ THE designation "Hot-Metal Ladle," when used in this report, will mean a vessel, lined with refractory material, used for conveying molten metal.

During the extensive growth of the steel industry there has been a consistent trend to increase the capacity of hot-metal ladles. Larger furnaces and the convenience of pouring the whole furnace charge into one ladle have combined to make this increase necessary. At the same time the allowable load on existing ladle cranes and supporting structures is limited, thereby rendering any decrease in ladle dead weight directly applicable to increased capacity for molten metal. The introduction of the welded type ladle in 1932 opened new possibilities for decrease in dead weight (2).* Oval shaped welded ladles came into use as an expedient to increase capacity without interference with height clearances and hook distances originally determined for the round riveted ladles.

Thus, larger ladles are being built, new shapes introduced, and the ratio of dead weight to ladle capacity is forced down. This continual development gives significance to the application of more rational and accurate stress analysis procedures in order to maintain the required safety and dependability of hot-metal ladles. Little design information is available in the technical literature. The design procedures used by the different ladle manufacturers apparently have given completely satisfactory ladles. However, these procedures are in general based on assumptions which have not necessarily been verified by tests.

A program of experimental and theoretical stress analyses of hot-metal ladles was therefore adopted by the Association of Iron and Steel Engineers as a part of the Standardization Committee's postwar program. Fritz Engineering Laboratory of Lehigh University undertook the task of investigating the structural behavior of such ladles, initial work starting on June 15, 1946. The general program was determined at a committee meeting in August 1946. It was decided to test 3 models based on prototypes of 150-ton net capacity. Both riveted and welded construction was considered, and a model of an oval ladle was included. Additional variables were: number and size of stiffener rings, size of trunnions, angle of tilt, amount of load, and distance between the points of support on the trunnion pins. The important problems involving stresses due to temperature differentials caused by the molten metal are not considered in this investigation.

A progress report was presented before the annual convention of the AISE in Pittsburgh, September 1947. The tests were completed in December 1947, and the experimental program, procedures and results are described in detail in a separate test report (1). The present report will therefore cover the conclusions only, illustrated by typical experimental data.

The interest and advice given by Mr. Ingvald Madsen, Research Engineer of AISE; Mr. F. E. Kling, chairman of the ladle design committee, together with other members of the committee, were essential factors in the planning and execution of the program. The valuable help of Mr. Paul Kaar, engineer of tests; and Mr. Kenneth Harpel, foreman, is acknowledged, together with the valuable help of the many student assistants in working up the strain gage data and preparing test result curves.

LADLE MODELS

The ladle types chosen for this investigation represent three general types in use in the mills. They also reflect different developments in ladle design. Ladle "A" is a round riveted ladle, Ladle "B" is an oval welded ladle, and Ladle "C" is a round welded type with a dished bottom. All three specimens are 1/5 scale models of

Presented before AISE Annual Convention, Cleveland, Ohio, September 28, 1948

* *Numbers refer to bibliography at end of report.*

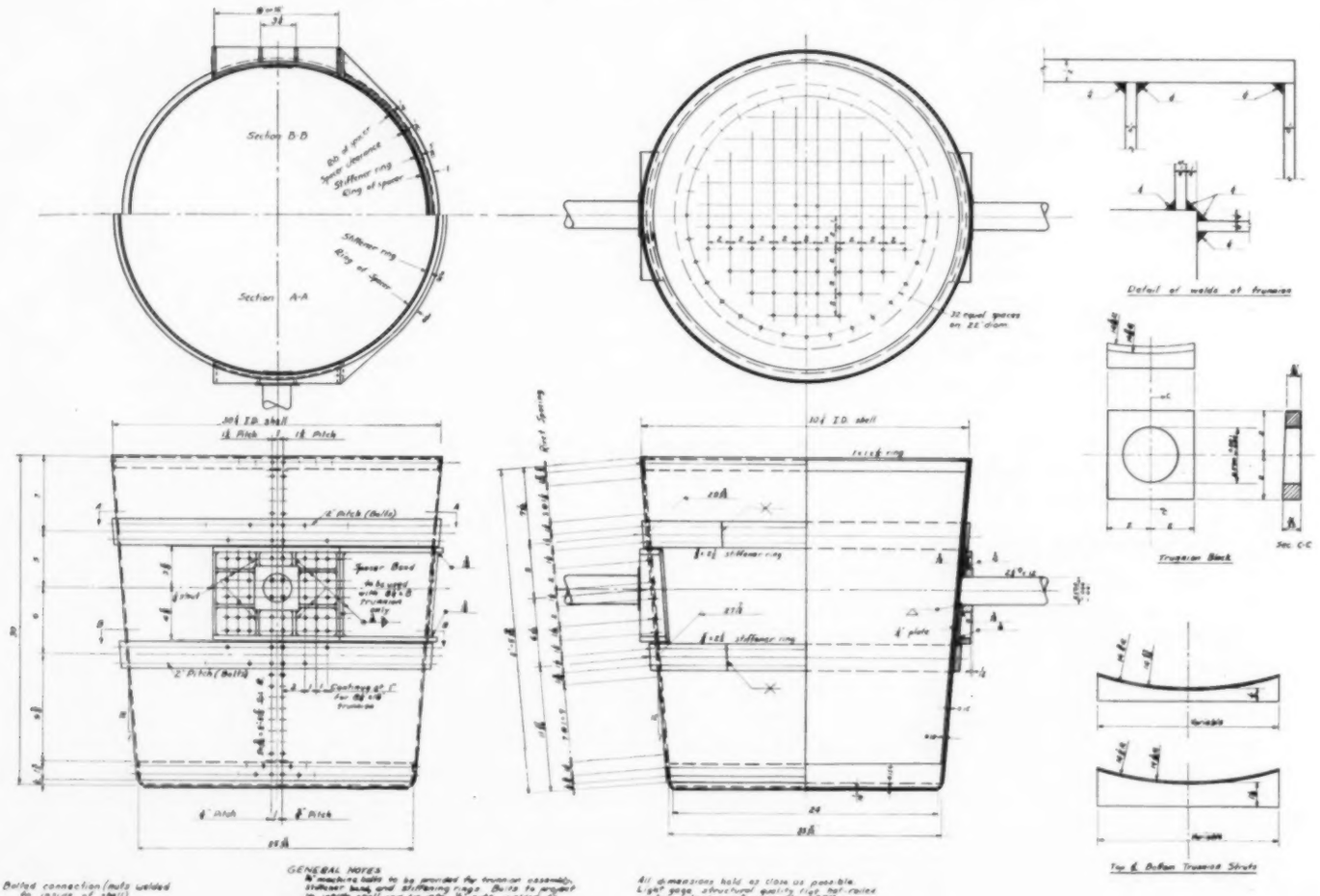
TABLE I

ACTUAL LADLE DIMENSIONS

Size in tons	Ladle shape	Type of construction	Ladle top diameter, ft-in.	Ladle height, ft-in.	Type of trunnions	Ladle shell			Ladle bottom			Method of pour	Date of design
						Side slope	Thickness, in.	Brick, in.	Shape	Thickness, in.	Brick, in.		
1.25	Round	Riveted	2-3½	2-4¼	Cast	¾ : 12	¼	4	Flat	¼	4	Top	1921
12	Round	Riveted	5-2	5-4	Cast	⅝ : 12	⅜	6	Flat	7/16	6	Top	1921
25	Round	Welded	6-7	6-7	Cast	¾ : 12	⅝	7¼	Flat	¾	7¼	Top	1943
45	Round	Riveted	8-11¾	8-9	Cast	2 7/12 : 12	¾	.....	Flat	⅞	....	Top	1926
50	Round	Rivet.-Weld.	8-4½	8-6	Rivet.-Weld.	¾ : 12	⅝	6	Flat	1	10	Bottom	1942
75	Round	Riveted	9-6¼	10-8	Cast	1 : 12	⅞	8¼	Flat	⅞	12	Top	1916
75	Round	Riveted	10-3	10-0	Cast	15/16 : 12	⅞	8-12	Flat	1⅛	15	Bottom	1928
100	Elliptical	Rivet.-Weld.	9-0 x 10-10¾	10-10½	Welded	¾ : 12	1⅛	7	Dish	1¼	9	Bottom	1944
120	Elliptical	Welded	9-7⅞ x 11-11⅞	11-4	Welded	⅞ : 12	1	5	Flat	1	8½	Bottom	1933
120	Round	Riveted	11-3	11-0	Cast	1:12	1	8¼	Flat	1¼	12	Bottom	1916
130	Round	Riveted	11-9¾	11-3	Cast	1 : 12	1⅛	.....	Dish	1½	....	Bottom	1943
150	Elliptical	Welded	9-10½ x 12-7	12-4½	Welded	⅞ : 12	1	6	Dish	1	12	Bottom	1940
150	Elliptical	Riveted	11-6 x 13-6	11-4	Cast	⅞ : 12	1¼	8	Dish	1¼	14½	Bottom	1937
150	Round	Riveted	12-7	13-2⅜	Cast	⅞ : 12	1	9	Flat	1⅜	13	Bottom	1929
150	Elliptical	Riveted	11-4 x 12-6	13-6	Cast	25/24 : 12	1	9	Flat	1¼	13½	Bottom	1929
150	Elliptical	Rivet.-Weld.	11-7¼ x 13-2½	12-1½	Rivet.-Weld.	⅞ : 12	1⅛	7-9½	Dish	1⅜	14½	Bottom	1943
190	Elliptical	Welded	11-5¾ x 14-5¾	12-11½	Welded	1 : 12	1⅛	8	Flat	1⅛	11	Bottom	1942
200	Elliptical	Rivet.-Weld.	10-10 x 13-10½	12-11	Welded	⅞ : 12	1¼	6¼-8½	Flat	1⅝	8	Bottom	1944

prototypes of 150-ton net capacity. A survey of some actual ladle designs is given in Table I for reference. The dimensions and material thicknesses are reduced from those of actual ladles approximately in the 5 to 1 ratio, although material availability was to some extent a determining factor. The trunnion pins on all ladles

Figure 1 — Ladle "A" is a one-fifth scale model of a 150-ton riveted round ladle.



were made long enough to permit study of the effect of hook spreading, as required by the test program.

Some simplifications were made in the model design, as compared with actual ladles. The slag spout and the pouring device were eliminated. Special joints for facilitating the transport of the ladles were not considered. The additional trunnion pins sometimes used when the ladle is placed in stands were disregarded. It is believed that the elimination of the slag spout at the lip of the ladle is the only significant deviation of those here mentioned. The test results indicate that the effect of the lip ring on the structural behavior of the ladle is greater than emphasized in present design procedures. The serious discontinuity introduced in this ring by the slag spout seems therefore to deserve special consideration. Tests with such spouts added on the models were proposed at one step in the development of the test program but were not adopted.

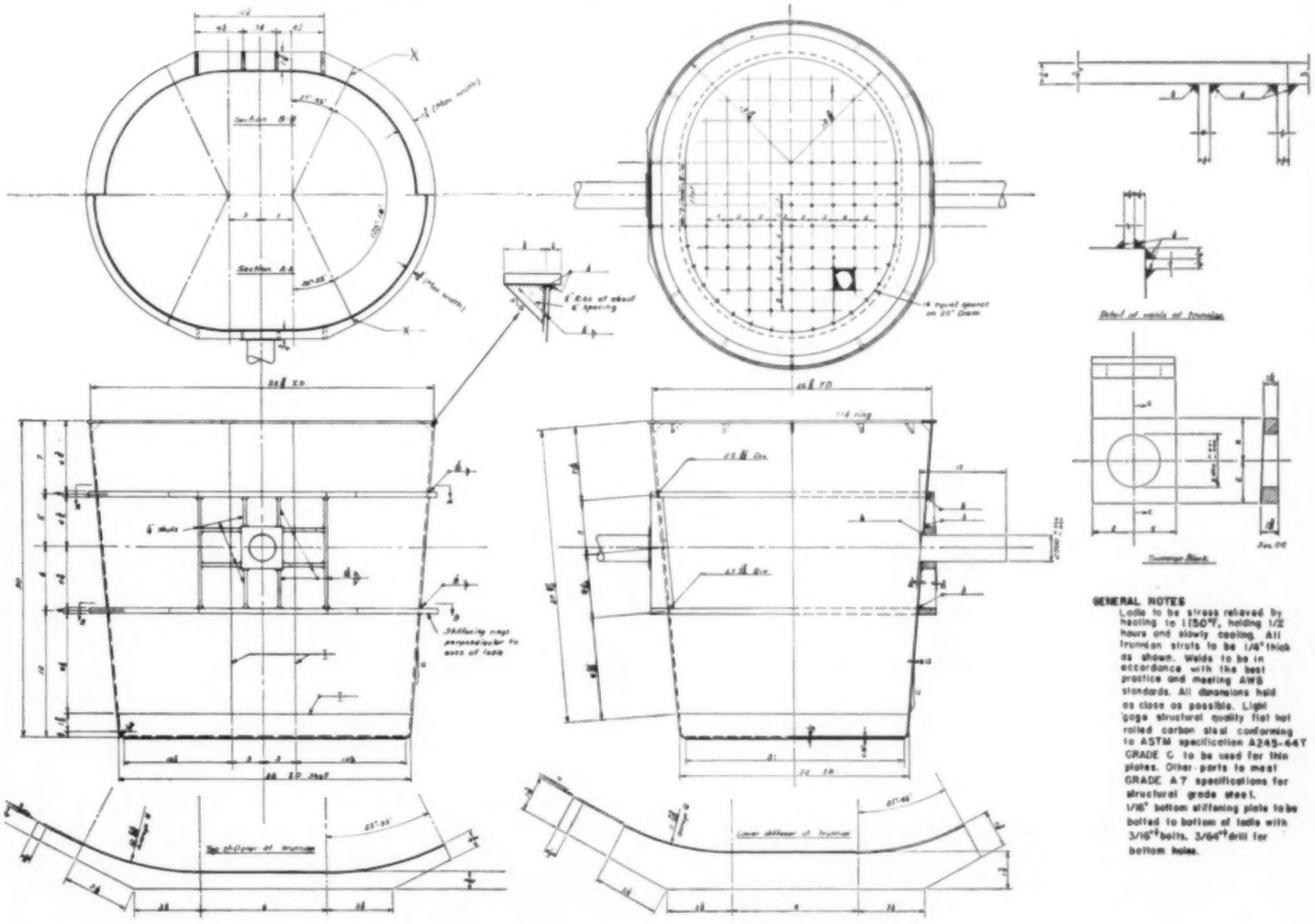
Ladle "A" is shown in Figure 1. Attention is called to the 1/16 in. additional plate on the bottom, similar plates on actual ladles being provided to protect against heat radiation during the pouring operation. Ladle "A" was tested with two different size trunnion pairs, also with or without a stiffener band combined with the small pair of trunnions. Figure 2 gives details of ladle "B." The oval shape of the ladle is obtained by inserting a straight middle section in the sides between the semi-circular parts of the cross section. Ladle "B" has a flat bottom with protection plate as in the case of Ladle "A." On Ladle "C," Figure 3, the bottom is dished and has no reinforcing plate. The stiffener rings are of equal size and comparatively small due to the heavier middle section of the shell between the rings. The trunnions are built up of plates with no ribs of the type used on Ladles "A" and "B," as may be seen from Figures 4, 5, and 6.

To conform with general practice in ladle manufacturing, the models were made of structural carbon steel conforming to ASTM Specification A-7 for heavier material, and to ASTM Specification A 245-44T, Grade C, for the thin plates. The models were stress-relieved for one half hour at 1150 F after fabrication. Before testing, the ladles were lined with fireclay in a way simulating the fire-brick lining used in actual ladles. The thickness of the fireclay was $\frac{3}{4}$ in. on the sides and 1 in. on the bottom, slightly more on Ladle "A."

TEST PROGRAM AND RESULTS

In the various tests, strains and deflections were measured at the points indicated in Figure 7 for Ladle

Figure 2 — Ladle "B" is a one-fifth scale model of a 150-ton welded oval ladle.


GENERAL NOTES
Ladle to be stress relieved by heating to 1150°F, holding 1/2 hours and slowly cooling. All trunnion struts to be 1/4" thick as shown. Welds to be in accordance with the best practice and meeting AWS standards. All dimensions held as close as possible. Light gage structural quality flat hot rolled carbon steel conforming to ASTM specification A245-44T GRADE C to be used for thin plates. Other parts to meet GRADE A7 specifications for structural grade steel.
1/16" bottom stiffening plate to be bolted to bottom of ladle with 3/16" bolts. 3/64" drill for bottom holes.

"A." The locations for the other ladles were similar. The strains were measured by means of bonded electric wire resistance gages, mounted on identical locations on the inside and outside ladle surfaces. The principal stresses and their directions, as well as the horizontal and vertical stress components, were computed from the measured strains. Horizontal deflections of the sides and vertical deflections of the bottoms were measured by means of mechanical deflection dials reading to 1/1000 of one inch. Figure 8 gives an over-all picture of the test set-up.

Actual ladles are loaded with molten metal weighing at an average 420 lb per cu ft. Due to obvious inconveniences in handling molten metal, mercury was used as loading agent in the laboratory tests.

A summary of the complete testing program is presented in Table II. The table lists the testing conditions for all tests on each ladle, and indicates the measurements taken in each case. The variables included in the test program may be found from a study of Table II, and will be pointed out in connection with the discussion of their effect on the structural behavior of the ladles. The complete set of data is given in the unpublished test report, as previously mentioned. The AISE may be consulted if some of this data should be desired.

The general structural behavior of the ladle models deviates considerably from what is often assumed as a basis for design. A description of this behavior will be given before the effect of the test variables is discussed.

Figures 9 and 10 show representative deflection results. They were obtained for ladle "A" under conditions explained in the figures. Figure 9 shows the general tendency of the horizontal cross section to become oval in shape due to the loading, the trunnion regions moving inward, and the regions between trunnions moving outward. Zero deflection is found approximately 45 degrees from the trunnion lines. The side deflections, as shown on vertical cross sections in Figure 10, are zero at the bottom and increase nearly linearly to the maximum at the lip. Some irregularity is caused near the trunnion pin by the concentrated hook reaction, especially for the larger hook distance. The bottom deflection gives the picture of a partially restrained circular plate under uniform load.

The stresses in the stiffener rings are primarily bending stresses, hence these stresses should be proportional to the change in curvature which may be visualized in Figure 9. This is confirmed by the stress measurements, as shown in Figures 11 and 12, for the outside and inside of the three stiffener rings on ladle "A." On each ring, the maximum stresses occur at the trunnion line and midway between the trunnions. The ring stresses are

Figure 3 — Ladle "C" is a one-fifth scale model of a 150-ton welded round ladle.

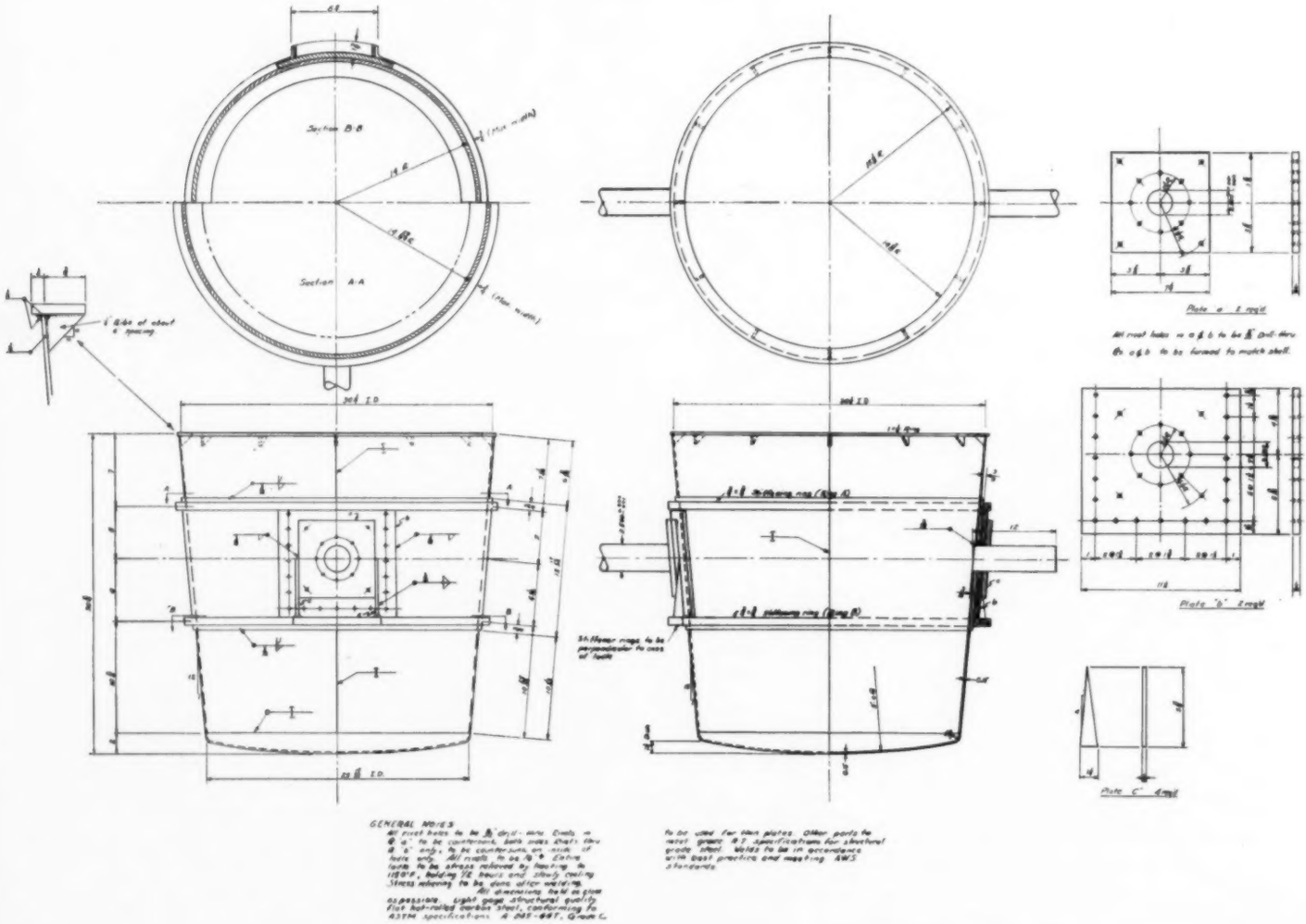


TABLE II

SUMMARY OF THE TEST PROGRAM

Entry No.	Model	Variables							Measurements		
		Loading agent	Trunnion size, in.	Other structural variables	(1) Load amount, per cent	(2) Hook dist, in.	Tilt angle, degrees	(3) Lining thickness, in.	Strains	Deflections	
										Side	Bottom
1		Mercury	8 x 8¼	With band	100	2½	0	½	x	x	x
2		Mercury	8 x 8¼	Without band	100	2½	0	½	x	x	x
3	Ladle	Mercury	16 x 8¼	Without band	25	2½	0	½	.	.	x
4	"A"	Mercury	16 x 8¼	Without band	50	2½	0	½	x	x	x
5		Mercury	16 x 8¼	Without band	75	2½	0	½	.	.	x
6		Mercury	16 x 8¼	Without band	100	2½	0	½	x	x	x
7		Mercury	16 x 8¼	Without band	100	7½	0	½	x	x	x
8		Water	12¼ x 10½	.....	100	2½	0	None	x	.	.
9		Mercury	12¼ x 10½	.....	7.2	2½	0	½	x	.	x
10		Water	12¼ x 10½	.....	100	2½	0	½	x	.	x
11		Mercury	12¼ x 10½	.....	25	2½	0	½	x	.	x
12	Ladle	Mercury	12¼ x 10½	.....	50	2½	0	½	x	.	x
13		Mercury	12¼ x 10½	.....	75	2½	0	½	x	x	.
14	"B"	Mercury	12¼ x 10½	.....	100	2½	0	½	x	x	x
15		Mercury	12¼ x 10½	.....	75	3½	0	½	x	.	.
16		Mercury	12¼ x 10½	.....	75	5½	0	½	x	.	.
17		Mercury	12¼ x 10½	.....	75	7½	0	½	x	x	.
18		Mercury	12¼ x 10½	.....	91	(4)	0	½	x	.	.
19		Mercury	10⅛ x 11½	With both rings	7.7	2½	0	½	x	.	.
20		Mercury	10⅛ x 11½	With both rings	50	2½	0	½	x	x	x
21		Mercury	10⅛ x 11½	With both rings	90	2½	0	½	x	.	.
22		Mercury	10⅛ x 11½	With both rings	90	3½	0	½	x	.	.
23		Mercury	10⅛ x 11½	With both rings	90	7½	0	½	x	.	.
24	Ladle	Mercury	10⅛ x 11½	With both rings	100	2½	0	½	.	x	x
25		Mercury	10⅛ x 11½	With both rings	100	7½	0	½	.	x	x
26	"C"	Mercury	10⅛ x 11½	With both rings	98	2½	± 6	½	x	.	.
27		Mercury	10⅛ x 11½	With both rings	82	2½	±20	½	x	.	.
28		Water	10⅛ x 11½	With both rings	100	2½	0	½	x	.	.
29		Mercury	10⅛ x 11½	Less lower ring	100	2½	0	½	x	.	
30		Mercury	10⅛ x 11½	Less both rings	100	2½	0	½	x	.	.

(1) Loads given in volume per cent of load when liquid level is 3 in. from the lip.
(2) Hook distance is measured from the inside of the shell.
(3) Lining thicknesses given in comparison with unworn lining on actual ladles.
(4) In this test the ladle was supported in stands.

largest on the lip ring and smallest on the lower stiffener, as are the deflections.

The normal stresses in the side shell are considerably less than the stiffener ring stresses, except near the juncture with the bottom plate. The same is the case for shear stresses in the side shell. Figure 13, giving the distribution of vertical normal stresses on ladle "B," clearly shows the high local stress peak near the bottom. These high stresses are similar to the discontinuity stresses produced near the heads of pressure vessels. This stress problem has been studied by the design division of the Pressure Vessel Research Committee of the Welding Research Council, and by several others. Although these stresses sometimes exceed the yield point, experience from actual ladles seems to show that they do not endanger the safety of the ladle. The high discontinuity stresses also occur on the bottom-plate side of the juncture. Except in this narrow region, the flat bottoms sustain mainly a high and nearly uniform bending moment throughout, while in the dished bottom smaller membrane stresses prevail.

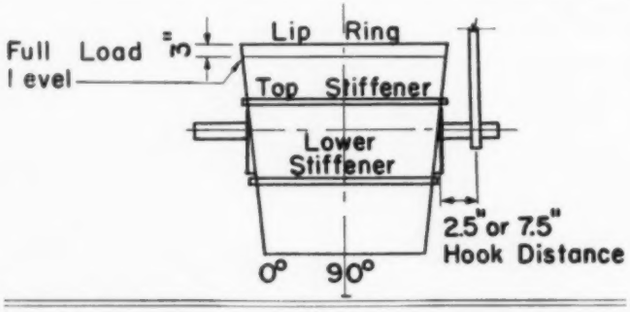
The general description of the structural behavior of the ladle models holds for all tests on all three models, and constitutes perhaps the most important result of this investigation. Actual ladles cover a large field of types and variations in design. The tests made will therefore not give the complete picture for any of them, but the general behavior as described is believed to be common for all types. The experimental program did, however, consider some of the more important factors in ladle design. The variables included may be divided into two groups, of which the first covers the variation in testing conditions, such as amount of load, distance between the hook supports, and angle of tilt. The other group includes structural variables; riveted versus welded construction, round versus oval shape, flat or dished bottom, trunnion assembly size, and type and number of shell stiffener rings. The effect of these variables will be discussed in the order mentioned.

The effect of amount of load on the deflections and stresses is partly demonstrated by Figures 9 to 15, and so is the effect of variation in the distance between the two supporting hooks. As a rule, stress and deflection data for the stiffener rings increase in almost linear proportion to both load and hook distance, as shown in Figures 16 and 17, respectively. Since the load distribution varies with amount of load, direct proportionality between load and stresses is not obvious. Table III shows the critical stresses in the rings for the smallest and the largest hook distance. A similar, but much less

TABLE III

EXPERIMENTAL STRESSES, PSI

Locations			1	2	3	4	5	6	7	8	9	10
			Full load — 2.5 in. hook distance							Full load — 7.5 in. hook distance		
0°: At trunnions 90°: Between trunnions 0 : Outside surface i: Inside surface			Ladle "A"			Ladle "B"	Ladle "C"			Ladle "A"	Ladle "B"	Ladle "C"
			8 x 8 in. Trunnions	8 x 8 in. Trunnions plus spacer band	8 x 16 in. Trunnions		With both stiffeners	Less lower stiffeners	No stiffeners	8 x 16 in. Trunnions		Both stiffeners
Lip ring	0°	0	—10,800	— 8,100	— 6,900		— 9,200	—11,200	—16,700	—12,200		—18,500
		i	+28,400	+22,800	+23,400	+ 9,200	+Yield	+Yield	+Yield	+33,600	+17,900	+Yield
	90°	0	+ 6,100	+ 4,900	+ 4,000	+ 2,800	+ 3,500	+ 4,700	+10,100	+ 7,700	+ 5,700	+ 6,000
		i	—20,900	—15,500	—18,000	— 6,300	— 5,900	— 7,700	—17,200	—29,800	— 7,500	— 9,500
Top stiffener	0°	0	— 6,500	— 5,400	— 2,200	—10,000	— 3,100	— 3,400	— 3,200	— 4,400	—22,100	— 6,700
		i	+ 3,600	+ 1,200	+ 1,600	+ 3,600	+ 3,700	+ 4,300	+ 4,100	+ 3,400	+ 6,800	+ 7,300
	90°	0	+ 4,400	+ 3,700	+ 3,500	+ 3,400	+ 5,300	+ 6,700	+ 1,700	+ 5,600	+ 6,400	+ 9,300
		i	— 2,800	— 1,800	— 2,000		— 3,400	— 4,600	— 2,700	— 3,100	— 4,200	— 5,700
Lower stiffener	0°	0	— 2,500	— 1,600	— 1,000	+ 1,600	— 400	+ 100	— 100	— 1,300	+ 3,100	— 200
		i	+ 2,000	+ 1,900	+ 400	— 100	+ 100	— 100	+ 100	— 700	+ 300	— 300
	90°	0	+ 4,700	+ 4,600	+ 4,200	+ 4,300	+ 4,200	+ 2,000	+ 3,600	+ 7,600	+ 8,400	+ 4,400
		i	— 2,300	— 1,300	— 1,900	— 3,300	— 2,300	— 1,300	— 2,700	— 4,200	— 7,000	— 4,400
Ladle dead weight, without lining, lb			280	350	310	250	340	333	325	310	250	340



consistent variation is obtained for the side shell. Bottom stresses and deflections also increase with the load, but less rapidly than in the rings. This should be expected, because membrane stresses prevail in the bottom when the deflections become larger than the plate thickness. Bottom stresses and deflections show very little response to an increase of the hook distance. One test was made with a ladle supported in stands, resting on the underside of the trunnion assemblies. This condition is essentially equivalent to a smaller hook distance, and the results fall in line with those given above.

Ladle "C" was tested in tilted positions up to 20 degrees, with no increase of the stresses. At more than 20 degrees, the stresses started to decrease due to outpour of the liquid load.

Ladle model "A" is riveted, while the two others represent welded construction. The three ladles differ also in other ways, and the test results are therefore not directly comparable. As an average, under equivalent conditions, the magnitude of the side deflections are about three times as large for the riveted ladle as for either of the two welded ones. This is at least partly explained by the fact that the average ratios of the bending stiffness of the stiffener rings above and below the trunnions are one third as great in the riveted ladle as in either of the welded ladles. The experimental stresses, essentials of which are given in Table III, show no consistent difference between riveted and welded construction. The structural efficiency of the ladles should be compared on a dead weight basis, since maximum live load within the ladle crane capacity limit is of prime interest. These weights are therefore given on the bottom of Table III.

Ladle "B" is an oval ladle, while "A" and "C" have circular cross sections. The deflections show the same trend for all three ladles, and the stresses do not allow any conclusions as to preference. It is believed that the small degree of ellipticity commonly used has but a minor influence upon the structural behavior.

Figure 4 — Trunnion assembly for ladle "A."

A study of the results from the tests of the flat bottoms on ladles "A" and "B" and the dished bottom on ladle "C" allows definite conclusions in favor of the dished type. As mentioned earlier, the dished bottom plate carries the load mainly through membrane stresses. The resulting deflection, Figure 15, is therefore only one sixth to one seventh of those developed in the flat bottoms, as shown in Figure 10. The figures also show a different deflected shape for the dished bottom, which does not have the maximum deflection at the center point. The only resemblance between the two types is the insensibility to variation in hook distance. The flat bottom plates sustain high bending stresses, while the dished shape shows tensile stresses throughout its thickness of about one fourth of the magnitude of the measured stresses on the flat bottoms. The discontinuity stresses both in the side shell and in the bottom plate near the knuckle is even more reduced when using a dished bottom.

Ladle "A," the riveted model, was tested with two sizes of trunnion assemblies, 8 and 16 in. wide, covering 34 and 68 degrees of the ladle circumference, respectively. The effect of the wider trunnions is to decrease the ring stresses, as seen from columns 1 and 3 of Table III. The reduction is largest on the lip ring and

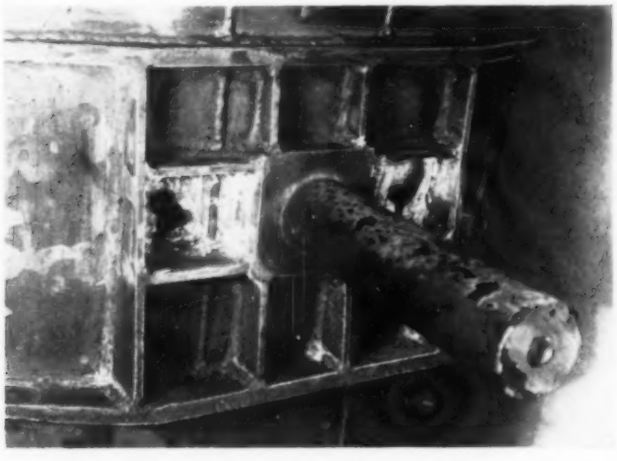


Figure 5 — Trunnion assembly for ladle "B."

on the top stiffener near the trunnion, and averages 43 per cent. The side deflections with the wide trunnions are about 75 per cent of those obtained with the narrow type. The bottom stresses and deflections stay practically unchanged.

Columns 1 and 2 in Table III give information on the effect of the addition of a spacer band on ladle "A." This $\frac{1}{4} \times 8\frac{1}{4}$ in. band, which is shown in Figure 1, is riveted to the sides of the trunnions, but not connected with the ladle shell. It is intended to carry most of the bending moment from trunnion to trunnion, thus relieving the regular reinforcing rings. Table III shows an average reduction in ring stresses with 26 per cent of those obtained without the spacer band. The additional weight of ladle steel material due to the band is 25 per cent. Stresses in the side shell are also decreased, although not altogether consistently. The bottom stresses are not affected by the addition of the spacer band. A comparison of columns 2 and 5 in Table III seems to indicate that the same advantage may be

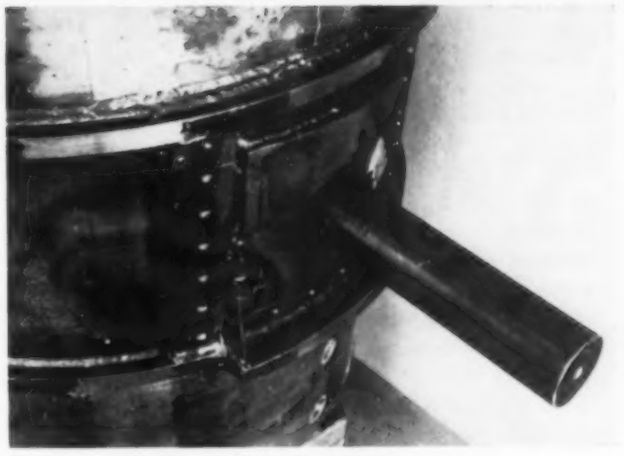


Figure 6 — Trunnion assembly for ladle "C."

obtained in a cheaper way by adding the equivalent steel weight to the ladle shell thickness between the top and lower stiffeners. Higher lip ring stress is registered in the latter case. Deflection tests show, on the other hand, that the heavier shell more effectively resists the local bending effects caused by the moments introduced through the trunnions.

Finally, the effect of removal of stiffener rings was investigated on ladle "C." Some of the test stresses are recorded in columns 5 to 7 in Table III. It should be remembered in interpreting these results that ladle "C" has a heavy middle shell section and correspondingly weak rings. Removal of the lower stiffener ring increases the stresses on the top stiffener by 23 per cent and the lip ring stress by 27 per cent on an average. With both the top and lower stiffeners removed, the lip ring stresses increase to an average of 143 per cent above those recorded with both stiffeners in place. No test has been made with only the top stiffener removed, but the tests made indicate that the top stiffener is comparatively more efficient than the lower stiffener. The deflection tests, Figure 15, also point to this conclusion, since the deformation at the top ring is considerably larger than at the other rings.

DESIGN RECOMMENDATIONS AND STRESS ANALYSIS

The conclusions which can be drawn from the test results, as presented in the previous chapter, are incorporated in the design recommendations below, which also summarize recommendations made in various articles on ladle design. Statements which are referred to articles and not to parts of this investigation should be regarded as the opinion of the author of the reference.

Material — Ordinary low-carbon steel is recommended for hot-metal ladle construction. The temperature effects and high cost discourage the use of high-strength alloys as a means of reducing the dead weight. For the trunnions, a 3 per cent nickel, low carbon steel is sometimes advised as being stronger and more resistant to spills of metal and slag (4). Reference 6 recommends forged steel ASTM A-235 Class B for the trunnions.

For trunnion pins and other parts for which reliable design methods allow the use of high stresses, the im-

portance of a smooth finish of the entire surface is emphasized (3).

Main ladle proportions — The ladles are usually shaped like a frustum of a cone with a side slope, or increase in radius, of one inch per 12 to 15 inches of the height.

The quasi-elliptical or oval cross section shape, introduced to increase the capacity under existing mill conditions, is usually obtained by inserting a straight shell section at the trunnions. By making these middle sections slightly curved, lining conditions are improved (5). The ratio of minimum to maximum cross section width usually falls between 1 and ¾. On the oval ladle model this ratio is 0.82. No noticeable difference was found in structural behavior between the circular and the oval ladle models. The round shape is preferred because of considerations of manufacturing cost and lining conditions.

In Figure 18, the ladle height and diameter, or average diameter for oval shapes, is given as a function of the carrying capacity for the ladles listed in Table I. A similar diagram for capacities up to 100 tons is given in Reference (3). It is seen that the height is slightly larger than the diameter up to approximately 12-foot height, or 125-ton capacity. Above that tonnage, the height is smaller than the diameter. In Reference (4) it is advised that the diameter only should be increased above 125-ton capacity in order to keep down the head of metal during pouring.

The location of the center of gravity of a fully loaded ladle of 12-foot height should be about 15 inches below the trunnion pin center line, and correspondingly placed

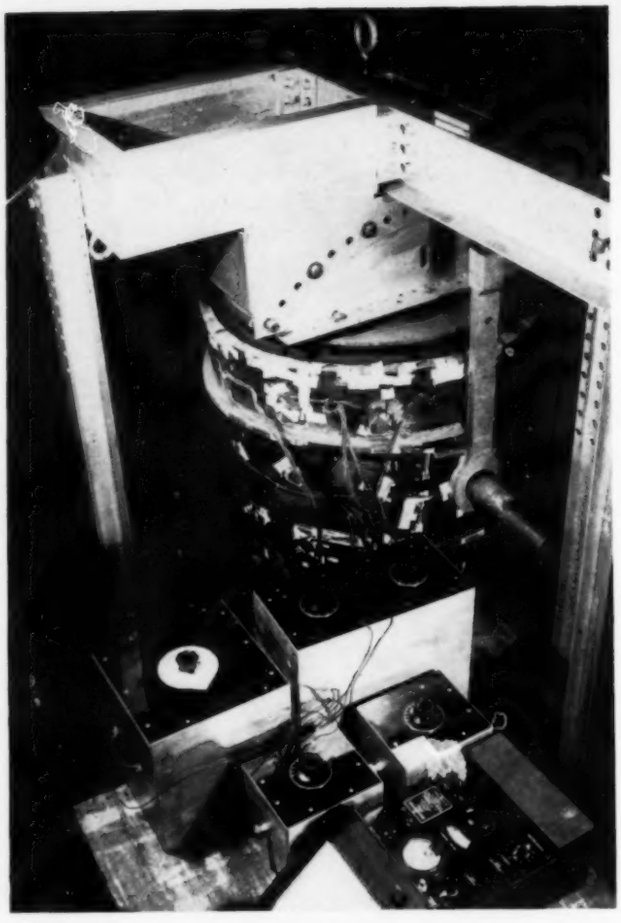
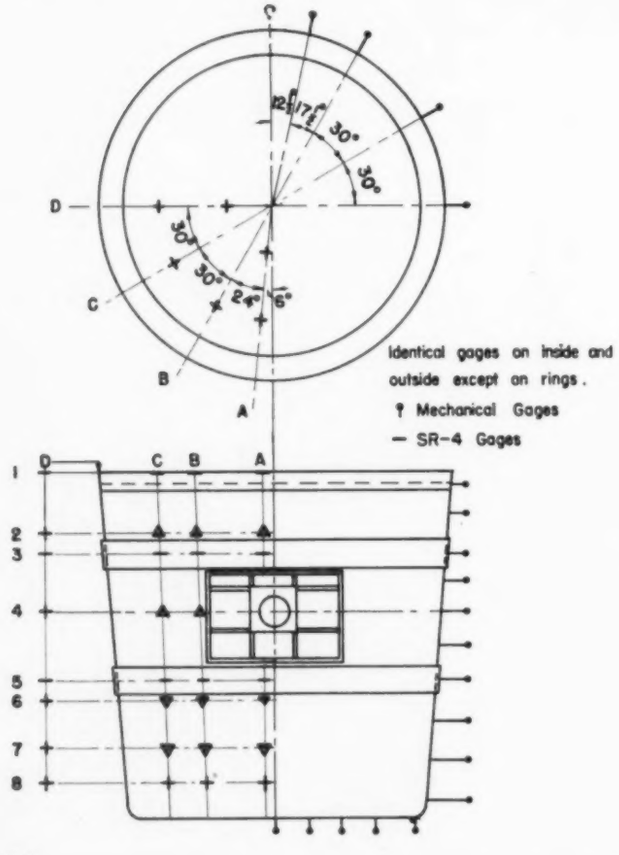


Figure 8 — In this setup for the strain tests, the equipment for measuring the strains is seen in the foreground. The ladle is seen in the background in the vertical position. Tape seen on the ladle is used to keep the leads from the electric strain gages in place.

Figure 7 — The general location of the gages are shown in this drawing for ladle "A." Similar locations were used on the other ladles.



for other size ladles (4). A method for calculating the location of the center of gravity and the tipping moment is given in Reference (10). In Reference (6) it is recommended that the center of gravity be $d = 6 + 0.09\ C$ inches below the trunnion center line, where C is the ladle capacity in net tons. If this formula is used, lock bars to prevent tilting should not be required.

Type of construction — The two commonly used types of ladle construction, riveted and electric arc welded, were both represented in the experimental investigation. The riveted model underwent much larger deflections than the welded ones under equivalent conditions, but this was at least partly due to the lighter design of the riveted model. The experimental stresses showed no consistent difference between the two types.

The steel weight of the riveted ladle model was 280 lb as compared to 250 and 340 lb for the two welded models (Table III). In actual ladle design, the older riveted types, without spouts, lining and stopper rings, weigh 21 to 27 per cent of the rated capacity. The same percentage for similar welded types of more than 50-ton capacity is only 16 to 17 per cent. Welding gives lighter ladles for capacities above 60-70 tons. Considering the weight of slag, lining, etc., welded construction allows an increase in capacity above that of riveted construction by about 7 per cent for a 150-ton ladle (4).

The joints in the shell should be butt welded. All welding should be specified in accordance with the

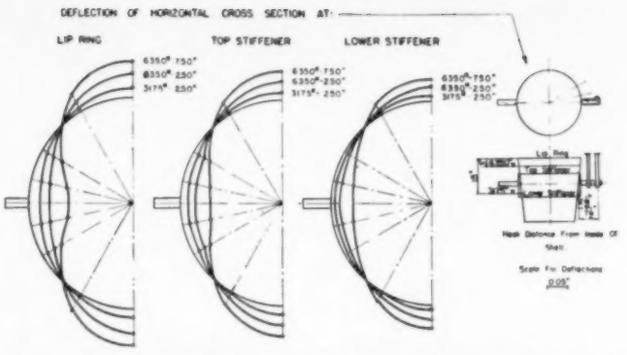
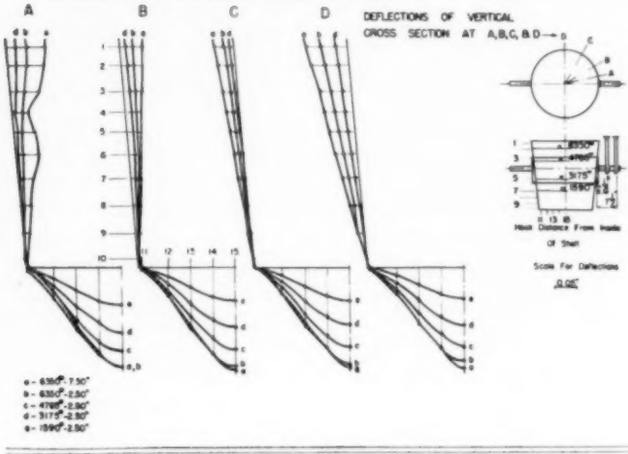


Figure 9 — The deflections for ladle "A" through horizontal planes are given for various loads and for two positions of the ladle hook on the trunnion.

Figure 10 — The deflections for ladle "A" through vertical planes are given for various loads and for two positions of the ladle hook on the trunnion.



applicable codes of the American Welding Society. The opinions on the necessity of stress relieving after welding seem to be divided. Most manufacturers, it is believed, stress relieve the ladles at 1200-1300 F for one hour per inch thickness of the heaviest material.

Design assumptions — The design assumptions should be in agreement with the general structural behavior observed during the tests. The ladle sides are found to deflect inward in their full height in the trunnion region, and outward in the region midway between the trunnions. The deflections are nearly zero at the bottom juncture, increasing approximately linearly towards the maximum deflections at the lip ring. A circular ladle cross section will, accordingly, tend to become elliptical under load, the amount of ellipticity increasing from bottom to lip. Vertical lines on the side shell located about 45 degrees from the trunnions experience no deflections. Thus, the maximum side deflections at each level occur along vertical lines through the trunnions and half-way between the trunnions, the absolute maximum being obtained at these locations on the lip ring.

The highest stresses on the reinforcing rings were obtained at the same locations, and followed the same pattern as the maximum deflections. High stresses were also measured in the bottom plates, and discontinuity peak stresses were found in a narrow region on both sides of the side-bottom juncture.

At these critical locations, as well as on other parts of the ladle, the most unfavorable condition is obtained with full liquid load and the longest distance between the supporting hooks. Tilting of the originally fully loaded ladle has no increasing effect upon the stresses. It follows that, in practical design, the ladle should be assumed loaded to the slag spout level with liquid metal, and the hook spacing should be chosen no larger than required by operating conditions.

Dead weight assumptions — The specific weight of molten metal varies with the grade of the steel. A suitable design value is 420 lb per cu ft. As mentioned earlier, the net dead weight of the ladle is close to ¼ of the rated capacity for riveted ladles, and 1/6 for welded types of more than 50-ton capacity. Spout, stopper, etc, will increase these fractions by 10-15 per cent. The weight of the fire-brick lining will vary with the preferred thickness. Common lining thicknesses are 9-14 in. on the bottom, and 9 in. decreasing to 7 in. on the sides from the bottom up. For ladles of about 150-ton net capacity, the lining weight is ordinarily 80-85 per cent of the total steel dead weight.

Trunnions — The trunnions on ladles of 100-ton capacity or more are usually of welded construction. Castings are now mostly used for smaller ladles. The trunnions should be connected to the stiffener rings which are usually provided above and below the trunnions in order to minimize local shell stresses due to the trunnion reaction. Tests show a beneficial effect of comparatively wide trunnions.

Figure 18 shows recommended trunnion pin diameters for different ladle capacities. Reference (6) advises that the pin diameter should not be reduced where it fits into the trunnion plate, and if the pin diameter is increased at that location, a large fillet radius should be provided. The stresses in the trunnion pins can be calculated by means of conventional methods.

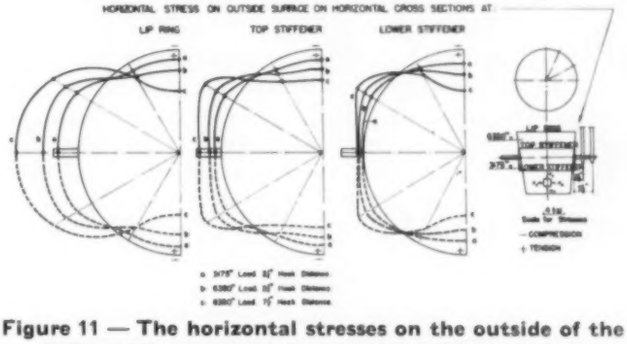
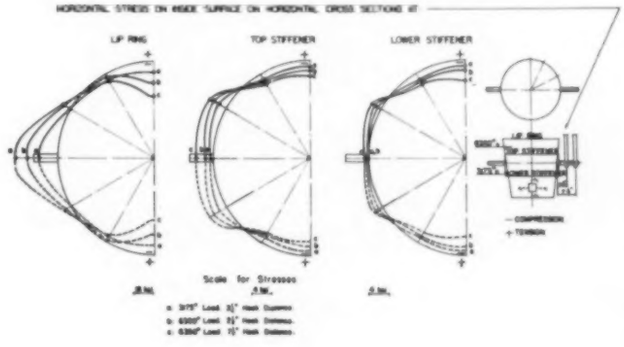


Figure 11 — The horizontal stresses on the outside of the ladle "A" are given for several loadings and hook distances for the ladle in the vertical position.

Figure 12 — The horizontal stresses on the inside of the ladle "A" are given for several loadings and hook distances for the ladle in the vertical position.



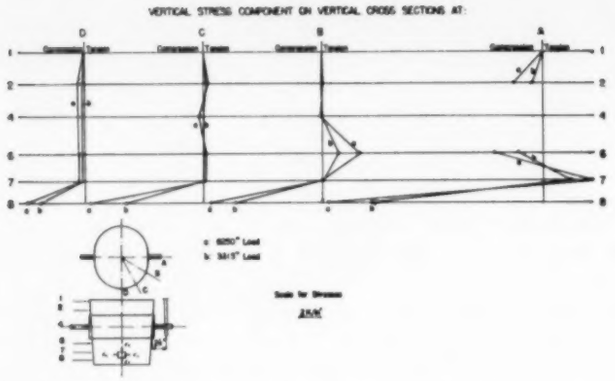


Figure 13 — Outside stresses through vertical planes of ladle "B" for two loads with a hook distance of 2½ in. from the inside of the shell.

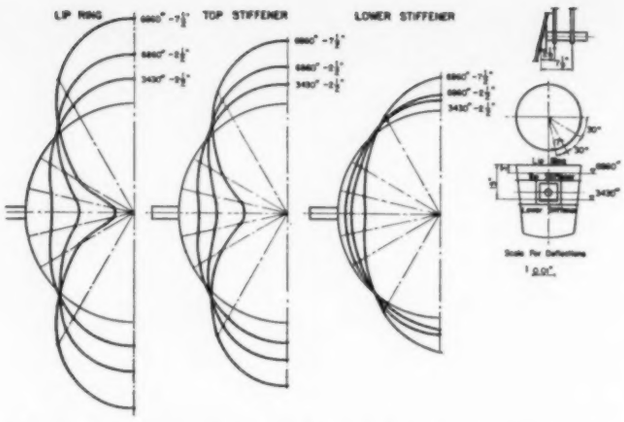


Figure 14 — The deflections through horizontal planes of ladle "C" are given for no-tilt of the ladle.

Side shell — The thicknesses commonly used for ladle side shells are within 10 per cent either way from those shown in Figure 18. In order to obtain comparable stresses in the model and prototype, the model shell thicknesses were made as small as possible, considering available materials. The model corresponds to a ¾ in. thickness on the 150-ton capacity prototype. The stresses in the model, loaded with mercury, should be about 3/5 of the stress in the corresponding prototype, loaded with molten metal. No severe stresses were observed, except near the bottom juncture, as shown in Figure 19, which records the average of the outside and inside side shell and bottom stresses for a section through ladle "C." Practical operating considerations probably require a thicker ladle shell than required by stress analysis, and the former will therefore be the determining factor in selection of the shell thickness, at least for ladles up to 150-ton capacity.

The problem of a strict analytical determination of the discontinuity stresses in the side shell near the bottom juncture is a very complicated one in the case of a ladle. The trunnion reaction caused a non-uniform distribution of these stresses around the ladle circumference, with a peak directly below the trunnions. Even on flat bottoms, a small knuckle radius is ordinarily provided, which further complicates the analysis. On riveted ladles, the lap-joint and the discontinuous connection add to the inadequacy of conventional stress calculation methods. Most disturbing, however, is the effect of the very large deflections of flat ladle bottoms.

A complete theoretical attack on the problem (not yet finished for use in practical design) is given in Reference (11). The problem is treated in a more practical way in Reference (12), and also in Timoshenko's "Theory of Plates and Shells," Chapter XI. The procedure below is based on the two latter references. Development of the formulas may be found in Reference (13).

With notation as explained in the nomenclature, and disregarding all the disturbing factors mentioned above, an impression of the magnitude of the discontinuity stresses may be obtained by the following procedure. Let:

$$\beta^4 = \frac{3(1-\nu^2)}{r^2t^2} = \frac{2.73}{r^2t^2} \quad \ldots\ldots (1)$$

The moment per inch of the circumference acting on the bottom end of the side shell is then, with Poisson's ratio taken as 0.3:

$$M_o = (-pr)\,\frac{0.525\ rt + 0.425\ \beta\ h^3}{4.200\ t + \beta^3 h^3 r} \quad \ldots\ldots (2a)$$

A positive moment caused tension at the outside shell surface. The radial end shear at the same location, positive when acting inward on the side shell, is:

$$P_o = \frac{0.425\ p}{\beta} - \beta M_o \quad \ldots\ldots (3a)$$

The moment acting in the vertical direction per inch width of the shell at any point at a distance y from the bottom juncture is:

$$M_y = M_o\ \phi + \frac{P_o}{\beta}\ \xi \quad \ldots\ldots (4)$$

and in the circumferential, or horizontal, direction:

$$M_x = 0.3\ M_y \quad \ldots\ldots (5)$$

The functions

$$\left.\begin{aligned} \phi &= e^{-\beta y}(\cos \beta y + \sin \beta y) \\ \xi &= e^{-\beta y} \sin \beta y \\ \psi &= e^{-\beta y}(\cos \beta y - \sin \beta y) \\ \theta &= e^{-\beta y} \cos \beta y \end{aligned}\right\} \quad \ldots\ldots (6)$$

where e is the base of the natural logarithms, are tabulated for values of βy between zero and 7.0 on page 394 of Timoshenko's "Theory of Plates and Shells," First Edition. Considering both the ordinary membrane stresses and the discontinuity effect, the total stresses in the shell near the flat bottom are then:

$$\sigma_y = \frac{pr}{2t} \pm \frac{6M_y}{t^2} \quad \ldots\ldots (7)$$

in the longitudinal direction, and:

$$\sigma_x = \frac{pr}{t} - \frac{2\ \beta\ r}{t}\left[\beta M_o\ \psi + P_o\ \theta\right] \pm \frac{6M_x}{t^2} \quad \ldots\ldots (8)$$

in the circumferential direction.

From the table referred to above it may be seen that the discontinuity stresses decrease rapidly with increasing distance from the bottom juncture. Beyond $\beta y = \pi$, or, using Equation (1) and $\nu = 0.3$,

$$y = 2.44\sqrt{rt} \quad \ldots\ldots (9)$$

TABLE IV

COMPARISON OF EXPERIMENTAL AND COMPUTED NORMAL STRESSES IN THE SIDE SHELL NEAR THE BOTTOM JUNCTURE MIDWAY BETWEEN THE TRUNNIONS — FULL MERCURY LOAD

Ladle	Distance from juncture (in.)	σ_x: horizontal σ_y: vertical	o: outside i: inside	Experimental stresses (psi)	Computed stresses (psi)	Ratio: computed / experimental
"A" Flat bottom	3.43	σ_x	o	+1,600	+ 800	0.50
			i	+ 0	+ 0	1.00
		σ_y	o	+2,200	+1,800	0.82
			i	—1,300	— 700	0.54
"B" Flat bottom	1.43	σ_x	o	—8,100	—8,200	1.01
			i	—5,600	—6,000	1.07
		σ_y	o	—4,600	—3,100	0.67
			i	+4,400	+4,100	0.93
"C" Dished bottom	0.10 (d = 1.90)	σ_x	o	—2,500	—8,200	3.28
			i	—4,500	—9,200	2.04
		σ_y	o	+2,100	+2,000	0.95
			i	—1,200	—1,100	0.92

These stresses are without any practical concern. The calculation above, on the other hand, will also show that the maximum stress for ordinary ladle dimensions exceeds the yield point. The maximum stress will, in most cases, occur in the longitudinal direction for $y = o$, and can then be computed by putting $M_y = M_o$ in Equation (7).

It can be shown, that the most favorable bottom shape from a combined economy and stress analysis point of view is an ellipsoid with a depth of about one quarter of the bottom radius. However, a shallower bottom, as generally used for ladles, in comparison with a flat bottom will greatly reduce the discontinuity stresses. The stress calculation in case of a dished bottom follows the same procedure and is subject to the same reservations outlined above for flat heads. Only the expressions (2a) and (3a) will be changed. Assuming that the ordinary two-radius dished bottom deviates little from the ellipsoidal shape, and that the knuckle radius is comparatively large, these expressions are substituted by

$$M_o = \left(-P_o\right)\left(\frac{h^{1.5} - t^{1.5}}{2\,\beta\,(h^2 + t^2)h^{0.5}}\right) \quad \ldots\ldots\ldots (2b)$$

$$P_o = \left(\frac{p}{2\,\beta\,d^2 h}\right)\left(\frac{r^2 t + 1.7\,(h\text{-}t)d^2}{4 + \frac{3h^2 - t^2}{h^2 + t^2}\left[\frac{h^{1.5} - t^{1.5}}{h^{1.5}}\right]}\right) \ldots (3b)$$

For bottom thickness h equal to the side shell thickness t the expressions become

$$M_o = 0 \quad \ldots\ldots\ldots (2c)$$

$$P_o = \frac{pr^2}{8\,\beta\,d^2} \quad \ldots\ldots\ldots (3c)$$

The tests of the ladles were not specifically designed

Figure 15 — The deflections through vertical planes of ladle "C" are given for no-tilt of the ladle.

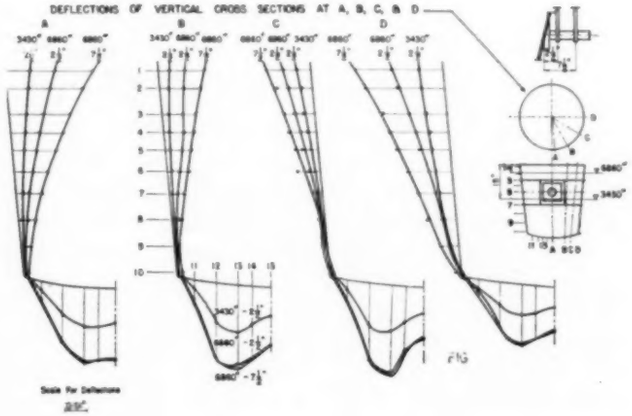
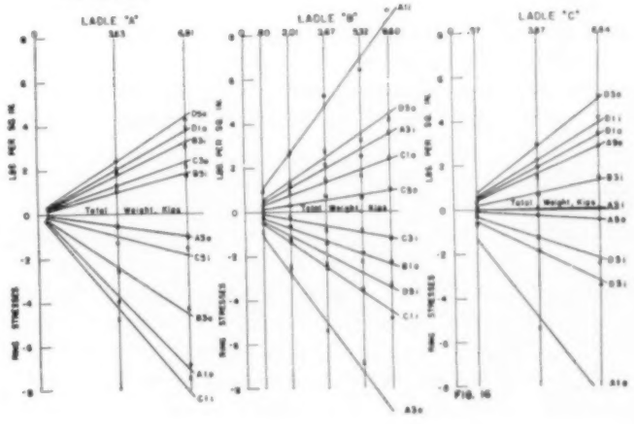


Figure 16 — The measured ring stress for different weights in the ladle indicate that they increase directly with the load.



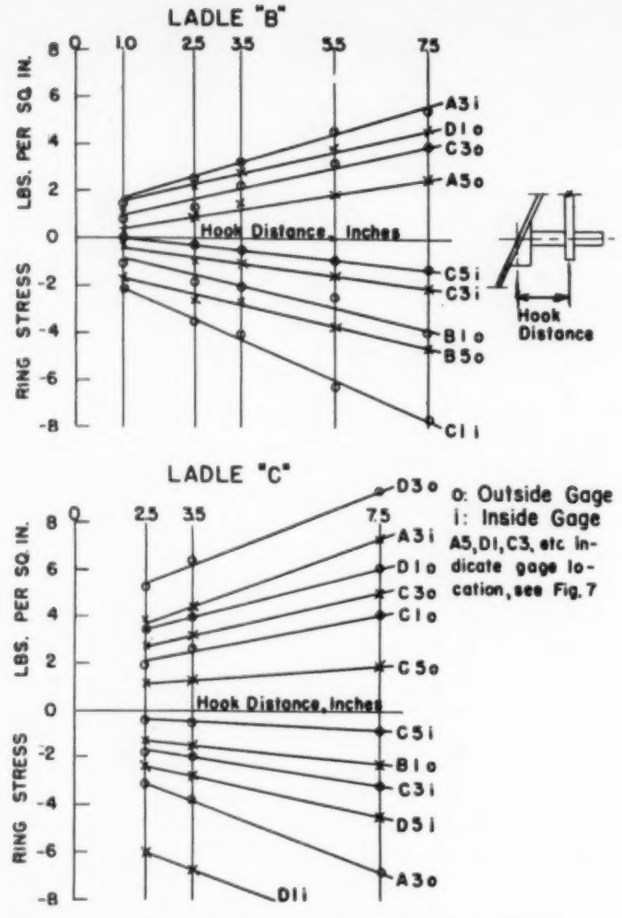


Figure 17 — The ring stresses increased directly with the moment arm of the ladle hook on the trunnion.

to investigate the problem of discontinuity stresses, which in themselves constitutes a large field of research. The deviations of a ladle from the ideal cases covered by the above formulas are also too many and significant to allow a close check with experimental stresses. A comparison, Table IV, is therefore carried out only for one gage point on each ladle located near the bottom juncture midway between the trunnions where the disturbances are smallest. The discrepancy in Table IV for the horizontal stress on ladle "C" may be explained by the location of the gage, which was mounted very close to the reinforced bottom butt weld. Also, the expressions (2b) and (2c) are not exact.

The corresponding experimental discontinuity stresses directly below the trunnions are two to four times as large as those midway between the trunnions. The calculated maximum stress at the juncture (y = o) is far above the yield point for ladles "A" and "B" with the flat bottoms, and 10,300 psi for ladle "C" with a dished bottom.

Bottom plate — A dished bottom is recommended as advantageous in several ways as compared to the flat type. The dished bottom is usually of the shallow dish type tank head, shaped like a spherical segment, with a smaller knuckle radius giving an arch tangent to the head flange (sometimes called torispherical). The maximum deflections of the flat plates were six to seven times as large as the maximum measured for the dished bottom, and exceeded the thickness of the bottom including the cover plate. The maximum deflection of the dished bottom was only about 0.2 of its thickness, and the latter also gave smaller over-all stresses. The discontinuity peak stresses at the juncture of side and bottom are greatly reduced when a dished bottom is used, especially if a large knuckle radius is provided. Flat bottoms usually become semi-dished after long service, indicating that the yield point is exceeded in some parts of the plate. The dished type provides inter-locking of the bottom fire-bricks, decreasing the danger of damage due to the liquid flotation force. One practical advantage of using a flat bottom is that the ladle may be set directly on the ground without danger of tilting.

The bottom should be furnished with a removable cover plate for protection against heat radiation during the pouring process. The cover plate is spaced away from the bottom by means of washers, and can be renewed or removed to allow inspection. The cover plate extends over the whole bottom or parts of it, according to the pouring schedule applied (4). A similar plate is also recommended underneath the slag spouts, extending down to the lower stiffener ring (6). Pouring openings in the bottom should be reinforced like holes on pressure vessels.

Common thicknesses of the main bottom plate, flat or dished, are shown in Figure 18. The thickness is usually a little larger than for the side shell, but may vary up to 20 per cent in either direction from those indicated in the figure. The tests showed that the bottom stresses depend only upon the depth of the liquid load, and that an analytical determination of the plate thickness must include both bending and membrane stresses.

For flat bottom plates, such a stress computation may be based upon the diagrams in Figure 20, reproduced from Timoshenko's "Theory of Plates and Shells," First Edition, pages 340 and 341. A ladle bottom edge is not completely fixed, as assumed in the diagrams. The strain measurements on the bottom were few (Figure 7), and do not coincide with the location of the stresses given in Figure 20. Although disregarded in actual design, the presence of the cover plate on the ladle model impedes a verification of the computed stresses. Using the added thickness of the main plate and cover, the diagram gives a maximum deflection of 0.17 in. as compared to 0.21 in. measured. The calculated model stresses at the center for full load are +22,100 psi at the outside and —11,700 psi at the inside surface. The corresponding experimental stresses at 0.32 times the bottom radius from the center point were +18,900 psi and —14,600 psi. The plate connection efficiency factor and the smaller actual degree of edge restraint add to give a too low calculated deflection and bending stress, and subtract in their effect on the calculated membrane stress. The maximum computed stress at center, which occurs on the outside surface, is believed to be a good criterion of the required plate thickness. The edge stresses will be smaller than given by this method due to imperfect clamping.

For a ladle of 150-ton capacity the empirical diagram in Figure 18 indicates a 1.3 in. thick bottom plate. With other dimensions as given in Figure 18, the stress in the bottom plate is found to be +33,200 psi and

—18,000 psi at the outside and inside surface at center, respectively. The experience that flat bottoms will undergo permanent deformation during service thus seems verified by stress calculation. Whether yielding should be tolerated as in the past, or be prevented by increasing the thickness or using a dished plate, will be a matter of judgment.

ASME's Boiler Construction Code of 1946, Sections I and VIII, for Power Boilers and Unfired Pressure Vessels, and also the joint API-ASME 1938 Code for Unfired Pressure Vessels for Petroleum Liquids and Gases, require a minimum flat head thickness h inches according to the formula

$$h = d\sqrt{\frac{cp}{s}} \quad \ldots\ldots (10)$$

where

d = plate diameter, or shortest span, in.
p = maximum load, psi
s = allowable unit working stress, psi
c = 0.25 for butt welded circumferential bottom joint
c = 0.30 for lap-riveted circumferential bottom joint

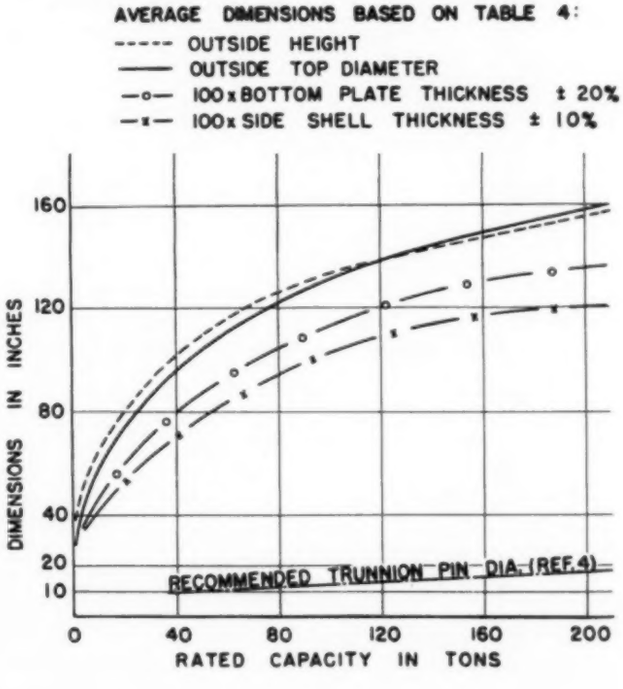
For the 150-ton prototype with 1.3 in. bottom plate, this formula gives 16,000 psi maximum stress. The formula thus leads to thicknesses of the order now ordinarily used, but fails to warn against the actual high stresses.

The codes mentioned above also give a formula for the required thickness of dished heads:

$$h = \frac{5}{6}\frac{pR}{s} \quad \ldots\ldots (11)$$

where the symbols have the meaning as explained for Equation (10). However, the codes restrict the radius of curvature, R, to be smaller than the bottom diameter. For hot-metal ladles this radius is usually much larger, and a too small thickness therefore results from this formula. Assuming radii of bottom curvature proportional to the one used on the model (Figure 3), Equation (11) gives a maximum bottom stress of about 15,000 psi for ladles of ordinary dimensions as shown in Figure 18. The actual stresses are larger. Thus, for the dished bottom model, Equation (11) gives s_{max} = 3,700 psi, where 8,100 psi was measured near the bottom center.

Figure 18 — The variation of ladle dimensions for various capacity ladles is given in this diagram.



The discontinuity stresses near the bottom edge are of a magnitude similar to those earlier discussed for the side shell. These stresses can only be reduced to below the yield point by using a dished bottom, and therefore were not discussed in connection with the design of flat bottoms.

A stress analysis procedure for dished bottoms will not be attempted here. The problem is discussed in the article "Stresses in Dished Heads of Pressure Vessels" by C. O. Rhys, ASME Trans. 1931. When finished, the work of reference (11) will probably give the most complete answer.

Reinforcing rings — The ladle models all had stiffener rings at the lip and above and below the trunnions. Investigation of the effect of the two trunnion rings indicated that the most efficient use of ring material is obtained at the location above the trunnions. Tests alone would suggest emphasizing the lip ring in ladle design. Practical experience shows, however, that the lip ring often suffers great damage from the hot slag and metal splash during service. The safety of a ladle should therefore not be made dependent on the presence of this ring. Also, the actual load carrying contribution of the lip ring may be lessened because of the discontinuity introduced by the spouts, which were eliminated on the models. It is therefore not recommended to follow the test indication towards an increase of lip ring dimensions. In order to meet the condition after long time service, the stresses should be calculated both considering and disregarding the lip ring.

Reinforcing of the shell against bending and twisting moments is sometimes accomplished by other means than the stiffener rings discussed above. A wide stiffener band, connected to the trunnions but not to the shell, reduced the experimental stresses. However, a similar result seems obtainable by adding the equivalent steel material to the regular stiffener rings or to the shell thickness between the trunnion rings. Reinforcing by means of a heavy middle shell section and rather small rings, as on one of the ladle models, was found to give a very rigid ladle with small deflections, but the stresses were not correspondingly reduced.

The locations and conditions for the maximum stiffener ring stresses are discussed earlier. It follows that, in designing the rings, it is sufficient to calculate the stresses at the trunnion line and midway between the trunnions on each ring for full liquid load and the largest hook spacing which may occur during operation.

The adjacent rings above and below the trunnion have an increased stiffness by virtue of their connection to the trunnion assemblies. Even if the trunnion assemblies are connected to the side shell only, as in the case of ladle "A" (Figure 1), the rings will be somewhat restrained in the neighborhood of the trunnions. Due to this effect, the two trunnion rings will ordinarily obtain the maximum stress midway between the trunnions, as may be seen from Table III. The increase in ring stiffness at the trunnions is not easily calculated.

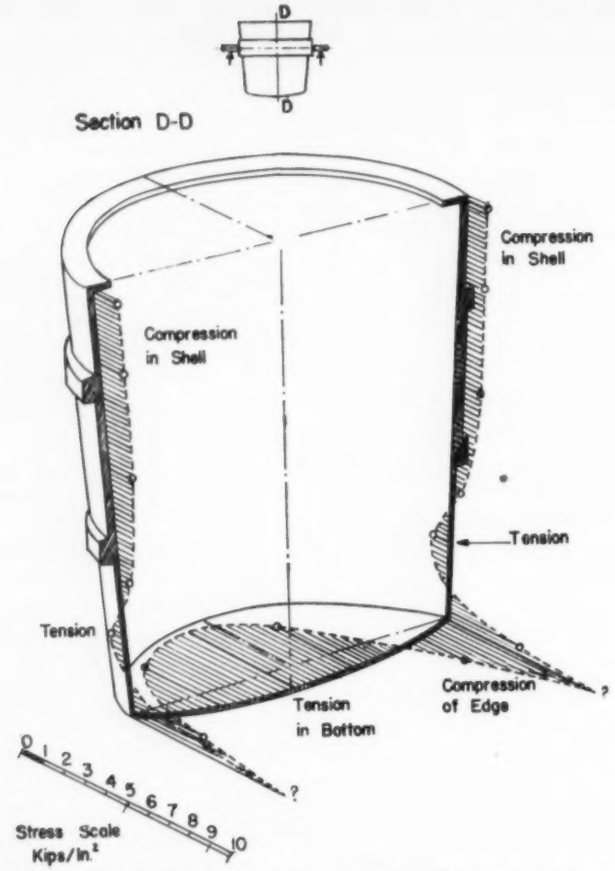


Figure 19 — Graphical view of horizontal membrane stresses on a vertical cross section halfway between the trunnions is here given for ladle "C" for full load, with no tilt of the ladle, and with a hook distance of 2½ in.

If the degree of restraint is obviously large, as for ladle "C" (Figure 3), the problem is of no consequence since the stresses midway between the trunnions will govern. The same is the case when wide trunnions are used: Rows 1 and 3 of Table III show that an increase of trunnion width from 34 to 68 degrees of the ladle circumference moves the critical section of the top stiffener from the trunnion line to midway between the trunnions. Without the increased strength due to the trunnions, all three rings would obtain maximum stress at the trunnion line. As earlier recommended, the trunnions should therefore be made comparatively wide, and be connected directly to the stiffener rings. Following this recommendation, it is necessary and sufficient to calculate the stresses at the following locations:

Lip ring (Ring 1): 0 and 90 degrees
Top stiffener (Ring 2): 90 degrees
Lower stiffener (Ring 3): 90 degrees

The designations are explained on Table III.

An exact analysis of the stresses in a hot-metal ladle, if possible, would be extremely complicated. A practical procedure must compromise between exactness and simplicity. The semi-rational method proposed emphasizes the latter. A more theoretical attack was attempted, using methods outlined in the article "Stresses in a Reinforced Monocoque Cylinder Under Concentrated Symmetric Transverse Loads," by N. J. Hoff, Journal of Applied Mechanics, Vol. 11, No. 4. Probably due to neglecting the bending stiffness of the side shell, this method gives unsatisfactory numerical results for hot-metal ladles.

The method given below is partly based upon general trends of the experimental results, which limits the range of its usefulness to ladles of types not basically different from those tested. Details in development of the procedure are avoided here, and are given in Reference (13).

The following are the assumptions on which the stress analysis procedure is based:

1. The deflections of the ladle side increase linearly, from zero at the bottom juncture, to a maximum at the lip.
2. The rings adjacent to the trunnion assemblies are subjected to concentrated inward transverse loads, as shown in Figure 21. When the lip ring is disregarded these loads are the only ring loads, and must therefore, acting separately, cause deflections in accordance with assumption 1.
3. The lip ring deflects in agreement with assumption 1 due to a loading imposed by a side shell shear flow q psi which, on a horizontal section through the ladle, is distributed according to
$$q = a_2 \sin 2\phi + a_4 \sin 4\phi \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (12)$$
where a_2 and a_4 are different in each of the shell fields between two rings or between the lower stiffener and the bottom. The angle ϕ is measured as shown in Figure 23.
4. The stiffener rings would experience no stress if the ladle were supported on an inward extension of the trunnion pins at points determined experimentally (Figure 23). The first assumption is in agreement with the test experience, demonstrated in Figures 10 and 15, that the ladle side deflects inward at all levels in the trunnion region. It was sometimes assumed in ladle design that the lower stiffener deflected outward in that region due to the moment introduced through the trunnion pin. The tests showed that this effect is of negligible importance.

The two concentrated loads P on each ring at each trunnion represent a simplification of the actual distribution of the load imposed upon the ring by the shear flow in the side shell. Assuming a triangular resultant load over the width of the trunnion assemblies, Figure 22, and P-loads are one third of the total trunnion width apart. This assumption gives stresses for different trunnion widths which are in good agreement with the experimental results. The use of concentrated loads on the rings adjacent to the trunnion assemblies, and a distributed loading on the lip ring, is most readily explained in connection with the fourth assumption. The radial deflections of a circular ring of uniform moment of inertia subjected to concentrated loads as explained are

$$\Delta_r = \frac{P r^3}{2EI}\left[\frac{\pi}{2} - \alpha + (2 - \cos\alpha)\sin\alpha - \frac{4}{\pi}(\alpha\sin\alpha + \cos\alpha)\right]$$

at the trunnions (0 degrees), and

$$\Delta_r' = \frac{P r^3}{2EI}\left[\frac{4}{\pi}(\alpha\sin\alpha + \cos\alpha) - 1 - \sin^2\alpha\right]$$

midway between the trunnions (90 degrees), an increase in radius being taken as positive. The fore-

going equations may be obtained from Reference (14), page 153. Assumption 2 then leads to the following relation between the loads P_2 on the top stiffener and P_3 on the lower stiffener:

$$P_3 = \frac{B_3}{B_2} P_2 \quad \ldots\ldots (13)$$

where B is the product of the ring bending stiffness and the distance of the ring from the bottom. For the lip ring,

$$B_1 = \frac{EI_1}{r_1^3} h_1$$

and for the top and lower stiffener the subscripts 2 and 3, respectively, are used.

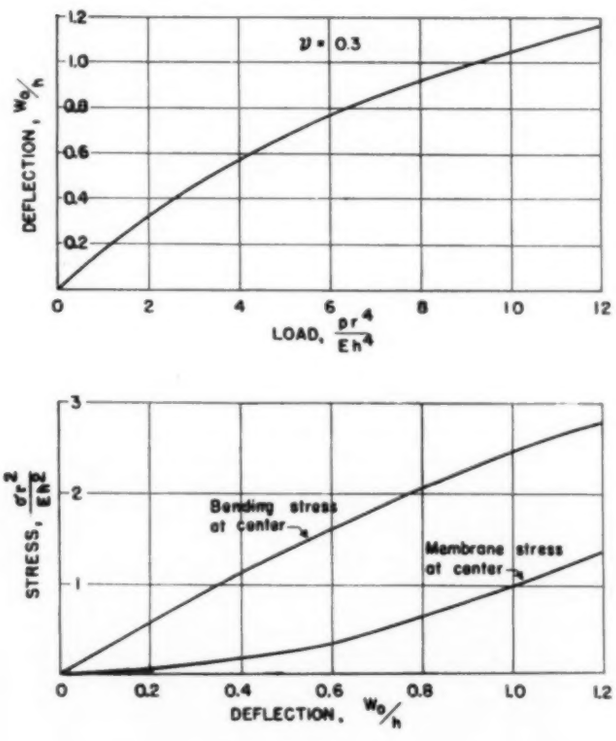
The skin shear is set up by the tendency for relative tangential movement between a ring and the adjacent side shell when the ring deflects. The skin shear must therefore be zero at $\phi = 0$ degrees and $\phi = 90$ degrees (Figure 23), where the ring deflections are purely radial. The shear distribution must also be symmetrical about the two axes of symmetry of a horizontal ladle cross section. A sine-series, using only the two first terms as in Equation (12), will satisfy these requirements. The additional terms cause negligible ring stresses, and are dropped.

The resultant skin shear load on a ring equals the difference in shear in the two shell fields adjacent to the ring. Writing

$$c_{22} = r_2 a_{22} - r_1 a_{12} \quad \ldots\ldots (14)$$

etc., where the first subscript refers to the ring number and the second subscript to the sine series term number,

Figure 20 — The deflections and stresses in a uniformly loaded circular plate with a clamped edge is given in this figure as presented by Timoshenko's "Theory of Plates and Shells."



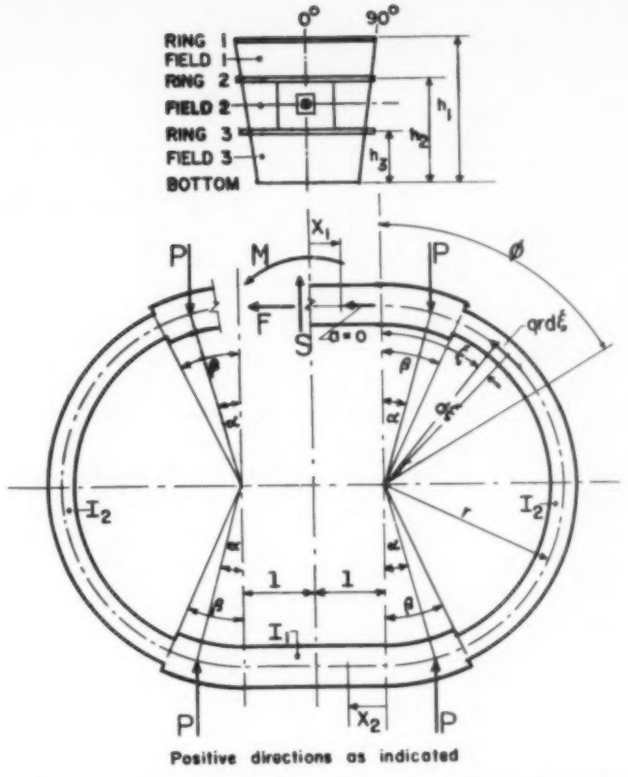


Figure 21 — The free body diagram which illustrates forces acting on the ladle are given in this figure.

the loadings over an arc $d\xi$ of the circumference of the rings are, avoiding details in the development,

$$\left.\begin{aligned} q_1 r_1 d\xi &= c_{12} \sin 2\xi + c_{14} \sin 4\xi \\ q_2 r_2 d\xi &= c_{22} \sin 2\xi + c_{24} \sin 4\xi \\ q_3 r_3 d\xi &= c_{32} \sin 2\xi + c_{34} \sin 4\xi \end{aligned}\right\} \quad \ldots\ldots (15)$$

For simplicity, these loadings are assumed to act at the neutral axis of the rings. (Figure 21.)

The fourth assumption listed above is in fair agreement with the deflection pictures, Figures 10 and 15. With the assumed P-loads and shear loadings, Equation (15), the equations expressing straight-line deflection of the sides at the trunnion line and midway between the trunnions may be written (13):

$$\left.\begin{aligned} c_{22} &= \frac{B_2}{B_1} c_{12} - P_2\, g(\alpha) \\ c_{32} &= \frac{B_3}{B_1} c_{12} - P_3\, g(\alpha) \\ c_{24} &= \frac{B_2}{B_1} c_{14} - P_2\, f(\alpha) \\ c_{34} &= \frac{B_3}{B_1} c_{14} - P_3\, f(\alpha) \end{aligned}\right\} \quad \ldots\ldots (16)$$

where $g(\alpha)$ and $f(\alpha)$ are given by Equations (24) and (25).

Figure 16 shows that the ring stresses are nearly proportional to the amount of load. Figure 17 indicates a linear relationship between the ring stresses and the hook distance. If the stress diagrams in Figure 17 are extended to the left, they will all cut the horizontal axis $\sigma = 0$ at or near one point, located approximately a distance r_t — r sin 45 degrees inside the ladle shell.

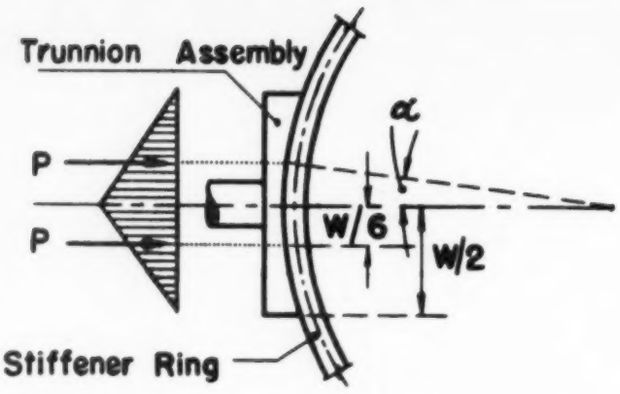


Figure 22 — A triangular resultant load is assumed to act over the width of the trunnion assemblies.

Thus, if the ladle were supported at such points, the ring stresses would become zero. Furthermore, the straight stress lines in Figure 17 show that the ring stresses are directly proportional with the distance "a," Figure 23, from the points discussed above to the actual point of support on the trunnion pins.

A free body diagram, obtained by cutting along section m-m, Figure 23, is shown in Figure 24. If the ladle were supported at a point on the vertical line through the intersection of section m-m and the bottom plate, the free body with zero ring stresses would be in equilibrium. Now, while moving the point of support the distance "a" to its actual location, ring stresses and the shell shear "S" on the cut section are set up. Including the horizontal normal shell forces in the components N_i of the ring forces at the cut section, equilibrium of the free body requires the moment about the lower end of the cut section to be zero:

$$\frac{W}{2}a - 2N_1h_1 - 2N_2h_2 - 2N_3h_3 = 0 \quad \ldots\ldots (17)$$

A similar free body diagram of the ladle cut along n-n, Figure 23, furnishes another moment equilibrium condition:

$$2N_1h_1 + 2N_2h_2 + 2N_3h_3 = 0 \quad \ldots\ldots (18)$$

Consistent with the assumed ring loadings it may be shown that,

$$N_2 = \frac{\sqrt{2}}{6}c_{22} + \frac{4\sqrt{2}}{30}c_{24} - P_2 \quad \ldots\ldots (19)$$

$$N_2 = -\frac{\sqrt{2}}{6}c_{22} + \frac{4\sqrt{2}}{30}c_{24} \quad \ldots\ldots (20)$$

Similar expressions hold for rings 1 and 3.

The development of suitable formulas for the ring loadings P_2, P_3 and the six c-coefficients now reduce to a matter of solving Equations (16) to (20). The resulting expressions are given in Equations (26) to (28).

Summarized, the stress analysis procedure for circular ladles includes the following steps. Use the auxiliary expressions:

$$a = r_1 - 0.7071\,r + e \quad \ldots\ldots (21)$$

$$B_1 = \frac{EI_1}{r_1^3}h_1\,,\quad B_2 = \frac{EI_2}{r_2^3}h_2\,,\quad B_3 = \frac{EI_3}{r_3^3}h_3 \quad \ldots\ldots (22)$$

$$k = \left(\frac{Wa}{4}\right)\left(\frac{1}{B_1h_1 + B_2h_2 + B_3h_3}\right) \quad \ldots\ldots (23)$$

$$g(\alpha) = 4.5\,[0.5708 - \alpha + (2 - \sin\alpha - \cos\alpha)\sin\alpha] \quad \ldots\ldots (24)$$

$$f(\alpha) = 225\,[2.5708 - \alpha + (2 + \sin\alpha - \cos\alpha)\sin\alpha - 2.5464\,(\alpha\sin\alpha + \cos\alpha)] \quad \ldots\ldots (25)$$

to determine the ring loadings:

$$\left.\begin{aligned} P_2 &= \left(\frac{Wa}{4}\right)\left(\frac{B_2}{B_2h_2 + B_3h_3}\right) \\ P_3 &= \frac{B_3}{B_2}P_2 \end{aligned}\right\} \quad \ldots\ldots (26)$$

$$\left.\begin{aligned} c_{12} &= -g(\alpha)\,B_1k \\ c_{22} &= -g(\alpha)\,[B_2k - P_2] \\ c_{32} &= -g(\alpha)\,[B_3k - P_3] \end{aligned}\right\} \quad \ldots\ldots (27)$$

$$\left.\begin{aligned} c_{14} &= -f(\alpha)\,B_1k \\ c_{24} &= -f(\alpha)\,[B_2k - P_2] \\ c_{34} &= -f(\alpha)\,[B_3k - P_3] \end{aligned}\right\} \quad \ldots\ldots (28)$$

The moments and normal forces in the stiffener rings are then,

In the lip ring, at 0 degrees:

$$M_1 = \frac{r_1}{60}(10c_{12} + c_{14}) \quad \ldots\ldots (29a)$$

$$F_1 = -\frac{r_1}{15}(10c_{12} + 4c_{14}) \quad \ldots\ldots (30)$$

In the lip ring, at 90 degrees:

$$M_1 = -\frac{r_1}{60}(10c_{12} - c_{14}) \quad \ldots\ldots (31a)$$

$$F_1 = \frac{1}{15}(10c_{12} - 4c_{14}) \quad \ldots\ldots (32)$$

In the top stiffener, at 90 degrees:

$$M_2 = -\frac{r_1}{60}(10c_{22} - c_{24}) + P_2r_2\,[1 - 0.6366\,(\alpha\sin\alpha + \cos\alpha)] \quad \ldots\ldots (33a)$$

$$F_2 = \frac{1}{15}(10c_{22} - 4c_{24}) - P_2 \quad \ldots\ldots (34)$$

In the lower stiffener, at 90 degrees:

$$M_3 = -\frac{r_3}{60}(10c_{32} - c_{34}) + P_3r_3\,[1 - 0.6366\,(\alpha\sin\alpha + \cos\alpha)] \quad \ldots\ldots (35a)$$

$$F_3 = \frac{1}{15}(10c_{32} - 4c_{34}) - P_3 \quad \ldots\ldots (36)$$

The sign convention applied above is shown in Figure 21. Tensile normal forces and moments causing tension at the outer ring surface are positive. The total ring stresses are finally found by means of the well-known formulas

$$\left.\begin{aligned} \sigma_o &= \frac{F}{A} + \frac{M}{S_o} \\ \sigma_i &= \frac{F}{A} - \frac{M}{S_i} \end{aligned}\right\} \quad \ldots\ldots (37)$$

where o stands for the outside and i for the inside ring surface.

The procedure above applies for circular ladles. For oval ladles, Equation (16) and consequently also Equations (26) to (28)* will include additional terms. If the ladle cross section deviates little from circular, as for most oval ladles, the effect of these additional terms are small. The procedure will then coincide for circular and oval ladles up to and including Equation (28).

The expressions for the moments in oval stiffener rings subjected to the P-loads and skin shear loads are slightly more complicated than those given above for circular rings. Oval rings also sustain additional moments due to the internal liquid pressure. The oval ring moments are then written, using the notation

$$u=\frac{l}{r_t} \quad \ldots\ldots (38)$$

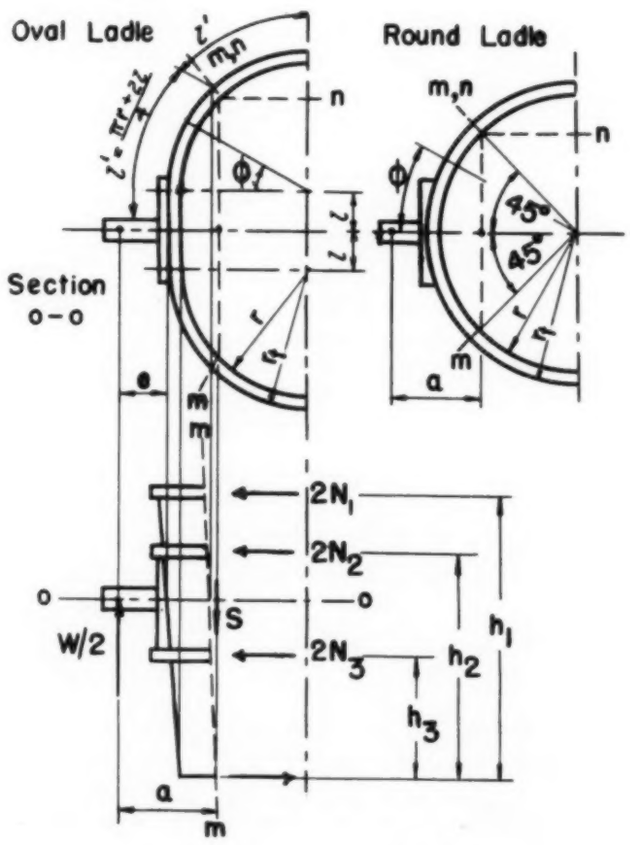
Oval lip ring, at 0 degrees:

$$M_1=\frac{\pi\, r}{60(\pi+2u)}\,(10c_{12}+c_{14}) \quad \ldots\ldots (29b)$$

* $a=r_t-r\sin\frac{\pi+2u}{4}+\phi$ ..... (21b)

instead of Equation (21) gives better agreement with test results for oval ladles. For u, see Equation (38). Oval lower stiffener, at 90 degrees:

Figures 23 and 24 — The stiffener rings would have no stresses if it were possible to apply the load to the trunnions at a point inside the ladle. This is illustrated by moment arm "a" shown in the upper part of the drawing (Figure 23). The lower part of the drawing (Figure 24) is a free body diagram taken through section m-m.



Oval lip ring, at 90 degrees:

$$M_1=-\frac{r_1}{60}\left[10c_{13}\left(\frac{\pi+4u}{\pi+2u}\right)-c_{14}\left(\frac{\pi}{\pi+2u}\right)\right] \quad (31b)$$

Oval top stiffener, at 90 degrees:

$$M_2=-\frac{r_2}{60}\left[10c_{22}\left(\frac{\pi+4u}{\pi+2u}\right)-c_{24}\left(\frac{\pi}{\pi+2u}\right)\right]\ldots\ldots$$

$$+P_2r_2\left[1-\frac{2(\alpha+u)\sin\alpha+2\cos\alpha}{\pi+2u}\right]$$

$$-\frac{V_2ur_2^2}{3}\left(3-\frac{6-2u^2}{\pi+2u}\right) \quad \ldots\ldots (33b)$$

$$M_3=-\frac{r_3}{60}\left[10c_{32}\left(\frac{\pi+4u}{\pi+2u}\right)-c_{34}\left(\frac{\pi}{\pi+2u}\right)\right]\ldots\ldots$$

$$+P_3r_3\left[1-\frac{2(\alpha+u)\sin\alpha+2\cos\alpha}{\pi+2u}\right]$$

$$-\frac{V_3ur_3^3}{3}\left(3-\frac{6-2u^2}{\pi+2u}\right) \quad \ldots\ldots (35b)$$

In the formulas above, V is the resulting load per unit length of the ring circumference. Roark's "Formulas for Stress and Strain," Second Edition, p. 261, gives

$$V_2=1.56\,\gamma\,H_2\sqrt{r_2t}\left(\frac{A'_2-v_2t}{A'_2+1.56t\sqrt{r_2t}}\right)$$

$$+\gamma\,H_2\,V_2 \quad \ldots\ldots (39)$$

The expression for V_3 equals Equation (39) except for the subscripts. V_1 is zero.

The normal ring forces F at 0 and 90 degrees are identical for circular and oval rings neglecting the small contribution from V.

In all the formulas given, the effect of the larger moments of inertia of the rings at the trunnions is neglected. The expressions for moments and normal forces in an oval ring with varying moment of inertia are given in Reference (13). The effect of varying moment of inertia is not large, and the exact formulas would not appeal to a design engineer.

From the interpretation of the experimental data, the effective width of shell on each side of a ring, acting together with the ring, was found to equal, at an average, the width of the ring itself. Figure 25 thus indicates the sections to be included in the cross section areas and the moments of inertia of the rings. The ring radius should be taken to the neutral axis of the section. For the tests of ladle "C" less one or both stiffeners (Table V), half of the thicker shell portion was included in the moment of inertia where a stiffener was removed.

The procedure outlined has been applied to the model ladles, and the results are listed in Table V together with the corresponding experimental stresses. The procedure fails in some cases to register the actual high lip ring stresses at zero degrees and cannot be regarded as perfect. To the best of the authors' knowledge,

TABLE V

COMPARISON OF COMPUTED AND EXPERIMENTAL STIFFENER RING STRESSES

Locations 0°: At trunnions 90°: Between trunnions o: Outside surface i: Inside surface			Full load — 2.5 in. hook distance					
			Ladle "A"				Ladle "B"	
			8 x 8 in. Trunnions		8 x 16 in. Trunnions			
			Computed psi	Measured psi	Computed psi	Measured psi	Computed psi	Measured psi
Lip ring	0°	o	— 7,200	—10,800	— 6,600	— 6,900	— 3,900	
		i	+21,900	+28,400	+20,000	+23,400	+ 7,900	+ 9,200
	90°	o	+ 5,300	+ 6,100	+ 5,300	+ 4,000	+ 4,100	+ 2,800
		i	—14,100	—20,900	—14,000	—18,000	— 7,600	— 6,300
Top stiffener	90°	o	+ 5,100	+ 4,400	+ 4,800	+ 3,500	+ 4,300	+ 3,400
		i	— 3,200	— 2,800	— 3,000	— 2,000	— 3,100	
Lower stiffener	90°	o	+ 4,500	+ 4,700	+ 4,000	+ 4,200	+ 5,400	+ 4,300
		i	— 2,400	— 2,300	— 2,600	— 1,900	— 5,100	— 3,300

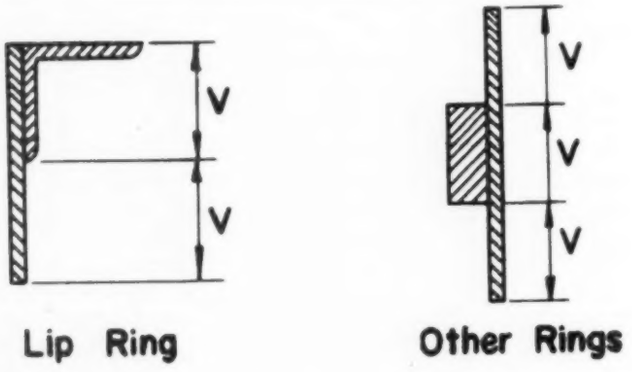


Figure 25 — The shell width which acts with the ring is given in this diagram.

however, it represents a distinct improvement over methods now in use.

The ring stresses listed in Tables III and V correspond to about 2/5 of the stresses for a prototype ladle loaded with molten metal.

NUMERICAL EXAMPLE

For a numerical stress analysis example, a round, welded ladle of 150-ton capacity is chosen, Figure 26. The ladle is meant to illustrate the procedure only, and does not necessarily represent a desirable design. Ladle height, top diameter, plate thicknesses and trunnion pin diameter are chosen in accordance with the empirical trend, Figure 18. The ladle capacity may be checked by means of the formula

$$W_c = \pi\gamma\, r^2 H + \frac{\pi}{3}\frac{\gamma}{s}(r_n^3 - 3r_n r^2 + 2r^3) \quad \ldots\ldots\ldots (40)$$

where the radii should be taken to the inside of the lining, which here is assumed to average 8 in. in thickness. With a maximum depth of 9 ft-6 in. of liquid metal, and $\gamma = 420$ lb per cu ft, Equation (39) gives $W = 150$ tons.

Only the stiffener ring stresses will be calculated here. The discontinuity stresses in the side shell may be found by means of Equations (1) to (9), and other stresses checked by conventional methods.

Figure 26 — The diagram shows the dimensions of the ladle used in the numerical example.

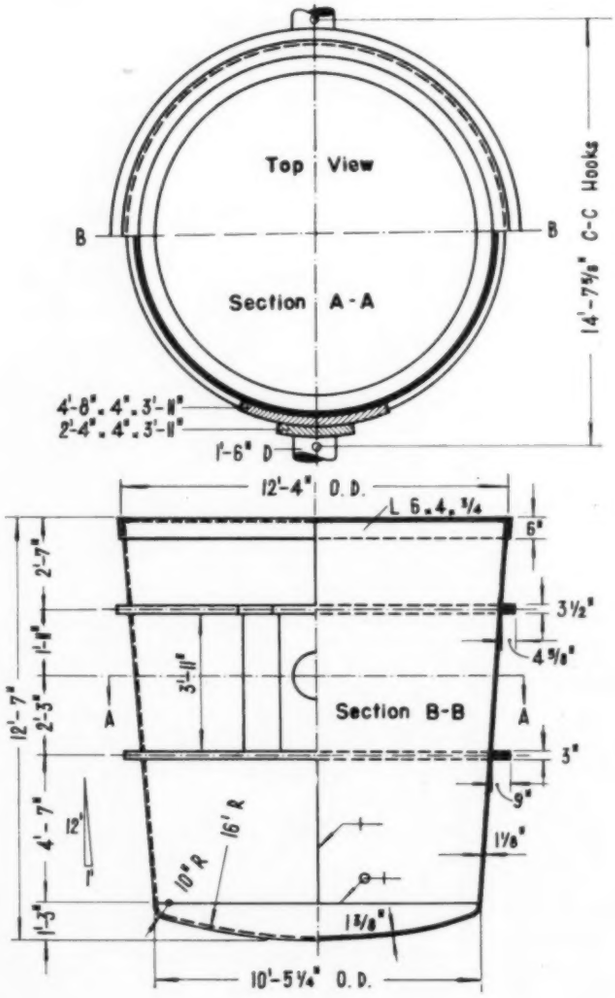


TABLE V — Continued

COMPARISON OF COMPUTED AND EXPERIMENTAL STIFFENER RING STRESSES

Locations			Full load — 2.5 in. hook distance						Full load — 7.5 in. hook distance					
			Ladle "C"						Ladle "A"		Ladle "B"		Ladle "C"	
0° At trunnions 90°: Between trunnions			With both stiffeners		Less lower stiffeners		Less both stiffeners		8 x 16 in. Trunnions				Both stiffeners	
o: Outside surface i: Inside surface			Computed psi	Measured psi	Computed psi	Measured psi	Computed psi	Measured psi	Computed psi	Measured psi	Computed psi	Measured psi	Computed psi	Measured psi
Lip ring	0°	o	— 5,300	— 9,200	— 8,700	—11,200	—18,900	—16,700	—11,000	—12,200	— 7,200		— 8,800	—18,500
		i	+11,100	+Yield	+17,100	+Yield	+37,400	+Yield	+33,300	+33,600	+14,800	+17,900	+18,500	+Yield
	90°	o	+ 3,900	+ 3,500	+ 6,300	+ 4,700	+13,800	+10,100	+ 8,800	+ 7,700	+ 7,600	+ 5,700	+ 6,500	+ 6,000
		i	— 8,100	— 5,900	—11,400	— 7,700	—24,900	—17,200	—23,900	—29,800	—14,100	— 7,500	—13,500	— 9,500
Top stiffener	90°	o	+ 8,200	+ 5,300	+ 8,400	+ 6,700	+ 5,900	+ 1,700	+ 8,000	+ 5,600	+ 8,000	+ 6,400	+13,600	+ 9,300
		i	— 5,200	— 3,400	— 5,000	— 4,600	— 6,200	— 2,700	— 5,000	— 3,100	— 5,700	— 4,200	— 8,600	— 5,700
Lower stiffener	90°	o	+ 4,800	+ 4,200	+ 1,600	+ 2,000	+ 3,500	+ 3,600	+ 6,500	+ 7,600	+10,100	+ 8,400	+ 8,000	+ 4,400
		i	— 3,000	— 2,300	— 1,600	— 1,300	— 3,700	— 2,700	— 4,300	— 4,200	— 9,500	— 7,000	— 5,000	— 4,400

The dimensions given in Figure 26 yield

$I_1 = 10.4$ in.^{4} $I_2 = 86.5$ in.^{4} $I_3 = 372.0$ in.^{4}

$S_{10} = 8.4$ in.^{3} $S_{20} = 24.6$ in.^{3} $S_{30} = 63.3$ in.^{3}

$S_{1i} = 3.8$ in.^{3} $S_{2i} = 38.9$ in.^{3} $S_{3i} = 87.7$ in.^{3}

$A_1 = 20.4$ in.^{2} $A_2 = 28.0$ in.^{2} $A_3 = 37.1$ in.^{2}

$h_1 = 136$ in. $h_2 = 105$ in. $h_3 = 55$ in.

$r_1 = 73.52$ in. r_2 71.32 in. $r_3 = 69.17$ in.

$t = 1.125$ in. $E = 30{,}000{,}000$ psi

$h = 1.375$ in. $w = 56.0$ in.

$e = 16.1$ in. $\sin\alpha = \frac{w}{6r_t} = 0.1300$

$r = 62.06$ in. $\cos\alpha = 0.9915$

$r_t = 71.75$ in. $\alpha = 0.1304$

Capacity, Equation (39), $W_c = 300{,}000$ lb

Steel dead weight $W_s = 0.19 W_c = 57{,}000$ lb

Lining $W_L = 0.85\ W_s = 48{,}000$ lb

$W = 405{,}000$ lb

Equation (21): $a = 43.13$ in.

Equation (22): $B_1 = 106{,}000$ lb $B_2 = 751{,}000$ lb

$B_3 = 1{,}855{,}000$ lb

Equation (23): $k = 0.0224$

Equation (24): $g(\alpha) = 2.496$

Equation (25): $f(\alpha) = 4.590$

The ring loadings are:

Equations (26): $P_2 = 18{,}100$ lb $P_3 = 44{,}800$ lb

Equations (27):

$c_{12} = -5{,}900$ lb $c_{22} = 3{,}300$ lb $c_{32} = 8{,}200$ lb

Equations (28):

$c_{14} = -10{,}800$ lb $c_{24} = 6{,}200$ lb $c_{34} = 15{,}100$ lb

The moments and normal forces in the rings due to these loadings become:

Lip ring, 0 degrees:

Equation (29a): $M_1 = -85{,}000$ lb in.

Equation (30): $F_1 = 7{,}000$ lb

Lip ring, 90 degrees:

Equation (31a) $M_1 = 59{,}000$ lb in.

Equation (32): $F_1 = -1{,}000$ lb

Top stiffener, 90 degrees:

Equation (33a): $M_2 = 430{,}000$ lb in.

Equation (34): $F_2 = -14{,}000$ lb

Lower stiffener, 90 degrees:

Equation (35a): $M_3 = 1{,}033{,}000$ lb in.

Equation (36): $F_3 = -35{,}000$ lb

By disregarding the lip ring

$c_{12} = c_{22} = c_{32} = c_{14} = c_{24} = c_{34} = 0$

and

Figure 27 — The graph shows numerical values of $g(\alpha)$ and $f(\alpha)$ as functions of the ratio of trunnion width w to the side shell radius, r_t at the trunnion level.

$$g(\alpha) = 4.5\,[0.5708 - \alpha + (2 - \sin\alpha - \cos\alpha)\sin\alpha]$$

$$f(\alpha) = 225\,[2.5708 - \alpha + (2 + \sin\alpha - \cos\alpha)\sin\alpha - 2.5464(\alpha\sin\alpha + \cos\alpha)]$$

where $\alpha = \sin^{-1}\frac{w}{r_t}$

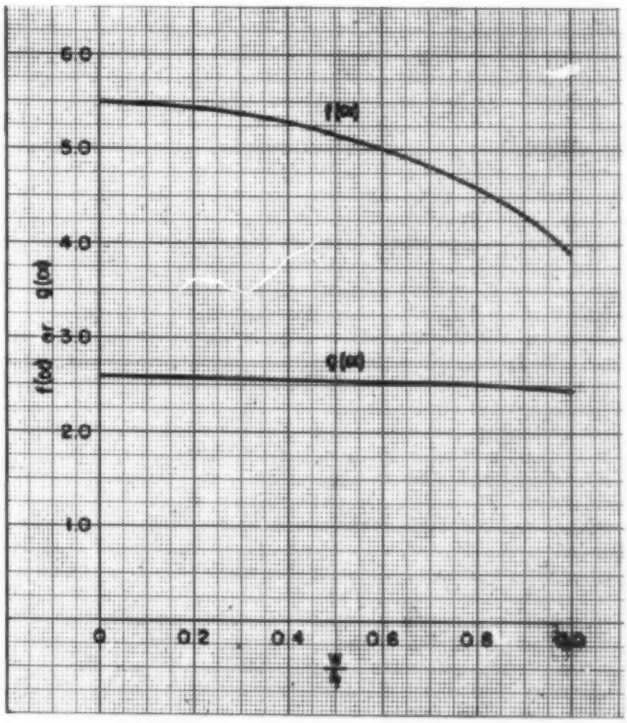


TABLE VI — CALCULATED CRITICAL RING STRESSES IN LADLE, FIGURE 26

Ring	Surface	Maximum stress with lip ring, psi	Maximum stress without lip ring, psi
Lip ring	o	— 9,800	.....
	i	+22,700	.....
Top stiffener	o	+17,000	+18,200
	i	—11,600	—12,500
Lower stiffener	o	+15,400	+16,300
	i	—12,700	—13,900

$P_2 = 18{,}100$ lb $P_3 = 44{,}800$ lb

as before the corresponding moments and normal forces in the stiffeners are, Top stiffener, 90 degrees:

Equation (33a): $M_2 =$ 463,000 lb in.

Equation (34): $F_2 =$ —18,000 lb

Lower stiffener, 90 degrees

Equation (35a): $M_3 =$ 1,109,000 lb in.

Equation (36): $F_3 =$ —45,000 lb

The unit stresses in the two cases, i.e. including and disregarding the lip ring, are now calculated by means of Equations (37). Table VI gives the resulting maximum stresses in each ring. The lip ring usually is considerably weaker than the other stiffeners and will show stresses which are nearly proportional to the depth of the ring. To avoid high stresses, as obtained in this example, the lip ring should be made even narrower than shown in Figure 26. Experience shows, on the other hand, that a yield stress in the lip ring does not endanger the safety of the ladle.

SUMMARY

Structural tests have been made of three 1/5 scale models of 150-net ton capacity hot-metal ladle prototypes. The results of the experimental and theoretical study are, in brief:

1. The structural behavior of hot-metal ladles deviates considerably from what has often earlier been assumed.
2. Under load, the ladle side deflections vary approximately linearly from zero at the bottom to the maximum at the lip. This deflection is inward in the trunnion region and outward between the trunnions.
3. The stiffener rings obtain the highest stresses at the trunnion line and midway between the trunnions. The lip ring carries the largest stresses, and the lower stiffener the smallest.
4. The side shell suffers only small stresses, except near the bottom juncture, where large discontinuity stresses are found.
5. Flat bottoms have very large deflections, and the stresses both at center and edge are likely to exceed the yield point.
6. Dished bottoms show moderate deflections and stresses, and are superior to the flat types.
7. Stresses and deflections increase nearly linearly with both amount of load and distance between the supporting ladle crane hooks, except for bottom stresses which are not affected by the hook distance.
8. Tilting of the ladle does not increase the stresses.
9. No major difference in structural behavior was found between riveted and welded ladles.
10. No major difference in structural behavior was found between circular and oval ladles.
11. Wider trunnion assemblies tend to reduce the stiffener ring stresses.
12. A spacer band or a heavy middle shell portion reduces the stiffener ring stresses approximately in proportion to the dead weight added by these members.
13. Although the load-carrying contribution of the stiffener rings increase with their distance from the bottom, the lip ring should not be emphasized in ladle design due to its exposure to damage. Design stresses should be calculated both considering and disregarding the lip ring.
14. Stress analysis procedures which give a fair agreement with the experimental results are proposed for stiffener rings, flat bottom plates, and the bottom-side juncture discontinuity stresses. A numerical design example is given. When finished, the work of the design division of the Pressure Vessel Research Committee may furnish a design procedure for dished bottoms.
15. Summaries of design practices and recommendations as given in various articles on hot-metal ladles are incorporated in this report.

NOMENCLATURE

Subscripts)

i = 1, 2, 3 for rings and shell fields as shown in Figure 21.
o = outside ring surface.
i = inside ring surface.

Roman alphabet)

a	Moment arm of trunnion reaction. (Figures 23 and 24.)
A_i	Area of effective stiffener ring cross sections.
A_i'	Net areas of stiffener ring cross sections, including only that shell in contact with ring.
B_i	Stiffener ring constants given by Equation (22).
c_{ij}	Coefficients of shell shear flow. Equation (14). First subscript refers to ring number, second to sine series term number.
d	Depth of dished head.
e	Distance along trunnion center line from center of supporting ladle crane hook to middle of side shell. (Figure 23.)
E	Youngs modulus.
$f(\alpha)$	A function of α given by Equation (25).
F_i	Normal force in rings.
$g(\alpha)$	A function of α given by Equation (24).
h	Bottom plate thickness, cover plate excluded.
h_i	Vertical distance from rings to bottom juncture.
H	Total maximum depth of liquid metal.
H_i	Head of liquid metal above rings.
I_i	Moment of inertia of rings.
k	An auxiliary constant given by Equation (23).
l	Half the length of straight shell section of oval ladle. (Figure 21.)

M_i Moment in rings.

M_o Moment per inch along juncture of side shell and bottom.

M_x Moment per inch of vertical section through side shell, or circumferential section through bottom plate.

M_y Moment per inch of horizontal section through side shell or radial section through bottom plate.

N_i Components of normal ring force at $\phi = 45$ degrees. Equation (19), (Figure 24).

N_i' Components of normal ring force at $\phi = 45$ degrees. Equation (20).

p Liquid pressure per unit area of bottom plate.

P_o Transverse shear on side shell per inch of juncture between side shell and bottom.

P_i Concentrated ring loads. (Figure 21.)

q_i Shear flow per unit length of horizontal sections through side shell.

r Bottom plate radius.

r_i Radii of neutral axes of rings.

r_H "Wet" radius at liquid metal surface.

r_t Shell radius at trunnion level.

R Radius of curvature of hemispherically dished bottom.

s Slope of ladle side.

S_i Section modulus of rings.

t Side shell thickness.

u Constant for oval ladles. Equation (38).

w_i Width of stiffener rings. (Figure 25.)

V_i Liquid pressure per inch of circumference of rings. Equation (39).

w Width of trunnion assembly. (Figure 22.)

W Total weight of loaded ladle.

W_c Ladle capacity. Equation (40).

y Distance along side shell meridian from bottom juncture.

Greek alphabet

α Half angle between concentrated ring loads. (Figure 22.)

β Side shell constant. Equation (1).

γ Specific weight of liquid metal.

ν Poisson's ratio, taken as 0.3.

ξ In ring analysis, an angle, Figure 21.

π $= 3.1416$.

σ Normal stress per unit area.

ϕ In ring analysis, an angle, Figure 21.

ϕ, ξ, ψ, θ In shell analysis, functions are given by Equation (6).

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1. "*Structural Tests of Hot-Metal Ladles*," by K. E. Knudsen, W. H. Munse and B. G. Johnston. Report to AISE, Standardization Committee, January 1948. Unpublished. Available for loan at Fritz Laboratory Lehigh University.

The results of a study of the structural behavior of hot-metal ladles are offered. Three 1/5 scale steel model ladles were tested for strains and deflections under static loads, disregarding the temperature effects of the molten metal. The models were: a round riveted ladle, an oval welded ladle, and a round welded ladle, all based on a prototype of 150-ton net capacity. The test results are given in the form of deflection diagrams, stress diagrams, and tables. The principal stresses as well as horizontal and vertical stress components, as presented, have been evaluated from the measured strains.

2. "*History and Use of Welded Ladles*," by F. L. Lindemuth, A.I.M.M.E. Iron and Steel Division, Open Hearth Comm., Open Hearth Proc. 1938, pp. 27-32.

Gives list of manufacturers, number and types of welded ladles made since 1932 and where located. Discusses savings in weight and some causes of cracks in the plates.

3. "*Ladle Design and Service*," by J. H. Hruska, "Blast Furnace and Steel Plant" v. 19, 1931, pp. 673-677 and 836-838.

Discusses the design and maintenance of steelworks ladles. Information is given concerning types of slag taken from ladles used for different classes of steel; the properties of ladle linings; the principal dimensions of refractory parts; the chemical composition of stopper parts and ladle nozzles; discusses methods of drying linings; emphasizes the importance of supporting parts.

4. "*Welded Ladles for Open-Hearth Service*," by F. L. Lindemuth, "Steel" v. 109, 1941. pp. 74-77.

Presents data on the design of round and elliptical welded steel ladles with capacities of 50-175 tons of molten steel. It is pointed out that with welded construction the weight of the ladle is about one-sixth that of the contents, whereas for riveted ladles the weight ratio is 1:4.

5. "*Welded Ladles Help Increase Steel Output*," by G. R. Reiss, "Steel" v. 112, 1943. pp. 112, 115.

By fabricating ladles from welded steel plates weight was reduced by over one-third, obtaining greater capacity without increasing total load on cranes.

6. "*Standard Design Specifications for Welded Steel Ladles*," Carnegie-Illinois Steel Corp., Operating Dept., Engineering Division. S. P. No. 2, Jan. 10, 1945. Unpublished.

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Description of the "Kling Ladle."

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Illustrated descriptions of hot-metal ladles and cars.

10. "*Ermittlungen Des Kippmomentes Und Der Kippkraft Einer Giesspfanne*," by B. Osann, "Giesserei-Zeitung" v. 22, 1925, pp. 44-46.

Determination of the tipping moment and tipping force of a ladle. Calculation of center of gravity; behavior of ladle at interruption of operation; tipping force at different tipping positions.

11. "*The Basic Elastic Theory of Vessel Heads Under Internal Pressure*," by G. W. Watts and W. R. Burrows, Standard Oil Co., Indiana, March 1949, p. 55, ASME Journal of Applied Mechanics, vol. 16, No. 1.

Means are outlined for calculating stresses and deformations at or near the junctures of vessel shells with flat, ellipsoidal and other type heads.

12. "*The State of Stress in Full Heads of Pressure Vessels*," by W. M. Coates, ASME Trans. v. 52, 1930, APM-52-12.

13. "*Structural Analysis of Hot-Metal Ladles*," by K. E. Knudsen, October 1948. Dissertation. Unpublished. Available for loan at Fritz Laboratory, Lehigh University.

Presents the development of the formulas given in this report and discusses other methods of attacking the stress analysis problem.

14. "*Formulas for Stress and Strain (1943)*, by R. J. Roark, McGraw-Hill Book Co.

DISCUSSION

PRESENTED BY

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F. LINDEMUTH, Chief Engineer, William B. Pollock Co., Youngstown, Ohio

B. G. JOHNSTON, Director, Fritz Engineering Laboratory, Lehigh University, Bethlehem, Pa.

K. E. KNUDSEN, Fritz Engineering Laboratory, Lehigh University, Bethlehem, Pa.

W. H. MURSCH, Staff Engineer, Carnegie-Illinois Steel Corp., Pittsburgh, Pa.

W. W. TRINKS, Associated Engineers, Pittsburgh, Pa.

J. A. EVANS, Assistant Chief Draftsman, Republic Steel Corp., Canton, Ohio

Leonard Larson: I believe that this program, as outlined and summarized in Mr. Knudsen's paper, is a fundamental step toward a clearer concept of what takes place in a ladle under load. For many of us, there have

been too many fluid spots in attempting to analyze stresses in ladles. In many cases we have probably treated these blind spots with our best judgment, which at times may not have been very sound. The fact that there have been so few mishaps with hot metal ladles indicates that at least we have exercised our ignorance on the safe side.

Tests to date have been made without hot metal in the ladle, so we still have one major blind spot, namely influence of heat from hot metal on ladle behavior.

F. Lindemuth: The ladle models had complete lip rings for retaining the lining at the top of the shells. In the tests these lip rings supplied a large percentage of the strength of the models. Mr. Knudsen has said in his discussion that in actual practice this lip ring should not be included in any strength calculations, and this point should be emphasized.

Member: I make a few ladles and I am quite interested in whether there are any records of failures. In other words, with all of these figures that we have, can we apply those to any ladles that have failed, except for heating and overloading? I know they are overloading ladles. We design a ladle for 180 tons and the first thing you know they have added to the top and it is a 225-ton ladle.

Bruce Johnston: We think it is of considerable interest, that all of the design procedures we were able to lay our hands on do not even give the correct sign of the stress. That is, where there actually is compression stress, the design procedure may indicate tension stress.

The method that Mr. Knudsen has developed in every case gives the correct sign of the stress and in most cases is within 10 or 20 per cent of the magnitude, so with these formulas you can be confident in the design of the ladle and know that the rings, at least, will not be overstressed.

Member: A question that comes into our operations a good many times is what are the steel companies to accept in the way of a factor of safety in ladles?

I think the answer to that, as far as we have figured out, is that we used to build the riveted ladles with a factor of safety of ten to fifteen and then, when cranes were being overloaded the users wanted lighter ladles so the steel companies began to drop their factor of safety.

My question is, how far can you carry that? It seems to me this committee should make some recommendations on what the factor of safety should be in a ladle.

Leonard Larson: I think the answer to that is arbitrary. That is, there would be as many opinions as there are individuals discussing it. However, certainly their ability to use better judgment has been sharpened by more information.

K. E. Knudsen: The last discussion mentioned the change from riveted to welded ladles. I should have mentioned, of course, we just have one riveted ladle and just two welded ones, so there is no broad basis for conclusions, but we did not find any basic difference in structural behavior.

Member: I think the answer to that is that you were working on the basis of a modern riveted ladle and a modern welded one. However, you go back ten or fifteen years and examine some of the riveted ladles we built ten or twenty years ago and you will find the factor of safety is much higher all of the way through.

K. E. Knudsen: That question, too, could not be decided from these tests at all. You have to take into consideration the temperature effect, of which we know very little.

Bruce Johnston: In connection with the factor of safety, I might say that you cannot know what your factor of safety is unless you know what your stresses are. Therefore, this report should provide a step toward a real factor of safety instead of a "factor of ignorance."

Leonard Larson: In considering factor of safety as related to objective of reducing excess weight in hot metal ladles by more intelligent design, it seems obvious to me that we must continue to provide for some abuse, and normal deterioration due to wear and tear. Where inspection and maintenance are below par, a higher factor of safety is necessary as compared with a higher level of inspection and maintenance. It is difficult to draw a definite line between economy and safety, where so many variables may be involved.

Wm. Mursch: In our office there are a good many specifications coming through for ladles. You look at these different specifications and drawings and see the different types of ribs and thicknesses of plates specified on these drawings for the same size ladles and you wonder which is the correct design.

In other words, for a 150-ton ladle one plant will have a bottom plate specified maybe an inch and an eighth thick and the same size ladle from another plant will specify an inch and a half thickness. The result is that we have never had any real criterion to tell what is a good design or a poor design. The question is always raised, which is right and which is wrong. Now, these formulas which have been presented in this paper will help in checking and in getting a ladle which is designed more theoretically correct than what we have had in the past.

W. W. Trinks: I would like to ask whether, in the test ladles, there was a lining?

K. E. Knudsen: Yes, we had one on all tests with a thickness of about ¾ in. on the side, and one in. on the bottom.

W. W. Trinks: This whole investigation was originally instituted, for the purpose of finding out whether welded ladles could be made lighter than riveted ladles. Did you reach a conclusion on that?

K. E. Knudsen: It was not the specific purpose; it was one of the purposes of the investigation. Although we had riveted and welded ladles, we did not find any major difference in stress behavior between the two.

J. A. Evans: Did you check the stresses by any known methods, such as strain gages or photo-elastic devices?

K. E. Knudsen: We used bonded electric strain gages.

Bruce Johnston: How many strain gage readings did you make?

K. E. Knudsen: On each ladle we had approximately 150 of these gages and we took in all about 14,000 readings measured by means of these electric strain gages.

Bruce Johnston: This last table he showed was the check between the strain readings and the method of analysis. Mr. Knudsen tried over thirty different empirical assumptions in arriving at the best check of all three ladles.

A Network System

FOR DYNAMIC LOWERING HOIST CONTROL

By D. L. PETTIT
Supervising Controller Design Engineer
Square D Company
Milwaukee, Wisconsin

. . . . the circuit described uses a minimum number of contactors to obtain six operating speeds . . . .

▲ DYNAMIC lowering hoist controllers are not new. Schemes of obtaining the dynamic characteristics for lowering vary with the individual originating them. However, the problem of producing the required features with a minimum of equipment has been so involved that there has always been room for further improvement in applying a solution.

The scheme presented in this article has to do with the application of a series, direct current motor for hoisting and lowering motions typical of cranes and hoists. A study of motor characteristics is not intended.

However, review of typical characteristic curves for a series wound motor (Figure 1) will assist in a more complete understanding of the comments which follow. Note particularly that the speed of a series motor approaches run-away condition as the torque is removed from the shaft. The dynamic lowering circuit should compensate for this characteristic by separate excitation of the series field, giving the motor characteristics which more nearly resemble those of a shunt motor, wherein the speed is reasonably stable with respect to load variations.

CIRCUIT REQUIREMENTS

The general circuit requirements that are used in hoisting involve a simple series connection so that high torque may be developed in lifting heavy loads. A shunting resistor is used across the field and armature to obtain a low torque, low speed characteristic to manipulate the light hook. This permits the operator to remove the slack from the cable in a safe manner as well as providing for extremely low speed when light loads are on the hook.

The shunting resistor is then removed to increase the hoisting speed, and the series resistance cut out in steps to further increase the speed. Full speed is obtained with the resistance all cut out.

For dynamic lowering it is necessary to energize the field and armature in separate parallel circuits so that the motor characteristics resemble those of a shunt machine. This gives stable lowering speeds when the load on the hook is transmitted back through the gear mechanism to the motor, causing it to rotate without the application of electric power. Power generated under these conditions is absorbed by dissipating it in resistors or returning it to the d-c line.

In order to assure adequate torque in the low speed in the first dynamic lowering point, a strong field is provided. A low voltage is applied to the armature circuit by means of a potentiometer connection, using the field circuit as the main path of the potentiometer.

Increases in lowering speed can be obtained by one of three methods—increase in potentiometer voltage connection, additional resistance inserted in the armature circuit, or field weakening. Field weakening is necessary to obtain approximately 200 per cent of full load speed for the maximum lowering speed. This latter condition is mandatory since one of the principal advantages in the use of the d-c dynamic lowering circuit

Presented before AISE Annual Convention, Cleveland, Ohio, September 30, 1948

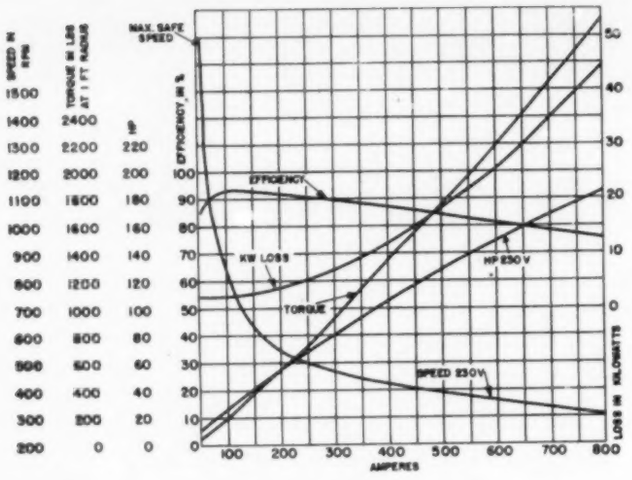


Figure 1 — Typical performance or characteristic curves for an AISE 612, 75-hp, 475-rpm, 230-v, series wound, d-c mill motor.

lies in the high speed lowering feature which may be obtained without introducing the difficulties usually encountered with load brakes.

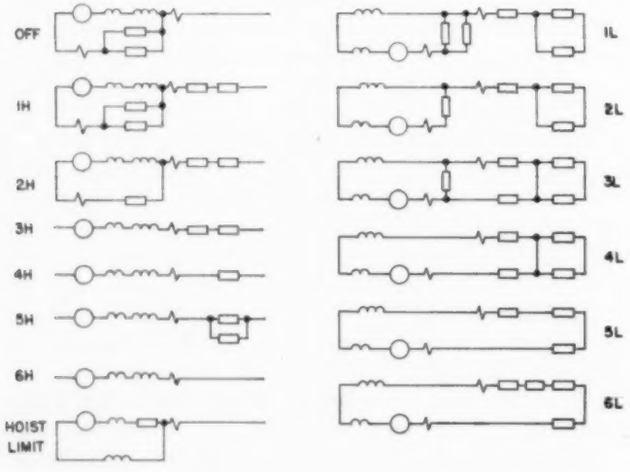
Conventionally, a series brake is employed. It offers the greatest safety. Braking action is spring applied when the current is off. It is sometimes difficult to secure adequate current to lift the brake on the first point hoist or lower, and also to connect the brake so that it will not carry the dynamic braking current when the controller is placed in the "off" position. As a further requirement, the brake must set in the event of a voltage failure which might be introduced by tripping of an overload device, opening of a fuse or circuit breaker or failure of the power supply.

Speed differences between the first few points on the master switch should be smaller than those when the master is near the high speed position. Such an arrangement improves the control which the operator has over the load when spotting. It is particularly desirable since it permits the operator to handle light as well as heavy loads with almost equal dexterity.

Transfers from point to point should involve current peaks held to a minimum, so that the commutator life of the motor is improved and erosion at the contact tips on the controller is minimized.

Automatic acceleration is introduced so that if the operator moves the handle too rapidly on the controller, time delay acceleration will be introduced for both hoisting and lowering. In this connection, it is not considered safe to introduce time delay deceleration, particularly in the lowering direction as such a scheme might take the control away from the operator just when it is needed most. Therefore, the operator must be depended upon to control deceleration in lowering if the motor and control are not to be abused. Rapid deceleration with reasonable safety is practical if the operator should encounter unusual circumstances requiring it.

Figure 2 — Step by step motor and resistor connections.



CIRCUIT EXAMINATION

The load and resistor circuit connections may now be examined by referring to Figures 2 and 3. Nine contactors and six resistor sections are employed, excluding the hoist limit circuit. Consider the dynamic lowering arrangement first.

A series parallel connection is used on the first lowering speed to obtain a field current which is between 100 and 200 per cent of full load current, depending upon the hook load. The armature is connected across the field itself through two parallel resistors. This gives a very low voltage impressed across the armature. The result of a strong field and a low armature voltage is a low speed for the first speed lowering. Notice that the series brake is connected outside the dynamic braking loop so that on this first point it must carry all of the current supplied to both the armature and field circuit. Such an arrangement insures prompt and positive lifting of the brake shoe when this connection is established.

The ohmic value of the resistors in series with the armature has been chosen to give smooth action on the first lowering speed. Proper choice minimizes the effect of the time delay in establishing the field. The momentary torque in the downward direction is, thereby, limited to such a magnitude that transient overspeeding before reaching the steady state condition is eliminated.

The transfer to succeeding speed points is accomplished by a unique circuit which depends for its success upon the use of two spring-closed contactors. In the second speed lowering, an increased amount of resistance is inserted in the armature circuit by opening one of the spring-closed contactors, permitting the load to accelerate the armature to a higher speed.

In the third speed, a bridge circuit is established increasing the potential across the armature which, in turn, increases the lowering speed. In the fourth speed, the other spring-closed contactor is opened, removing the bridge circuit, leaving the armature tied through a resistor to the resistor network in such a way that the voltage is further increased, giving a higher lowering speed. During these transfers it will be noted that a closed loop consisting of the armature, the field, and some resistors is maintained in such a way that regeneration can be dissipated at all times.

Fifth speed is obtained by applying approximately

line voltage to the armature by opening contactor 2A and closing contactor 2M. The field carries slightly less than full load current. Only resistor 4 is in the circuit and it seems to limit torque and current between the accelerating points in the lowering direction. It will be observed that by closing contactor 2M after contactor 2A is open, instead of the reverse sequence, current peaks are reduced. Reverse order would result in extra current drawn momentarily for the field as well as the armature. Early opening of 2A eliminates such current peaks and contributes to the smoothness with which the load is accelerated downward.

A pneumatic timer is used so that a time delay must elapse before the fifth speed point can be used. It has been arranged so that immediate transfer from speed 4 to speed 5 can be obtained if operation has occurred

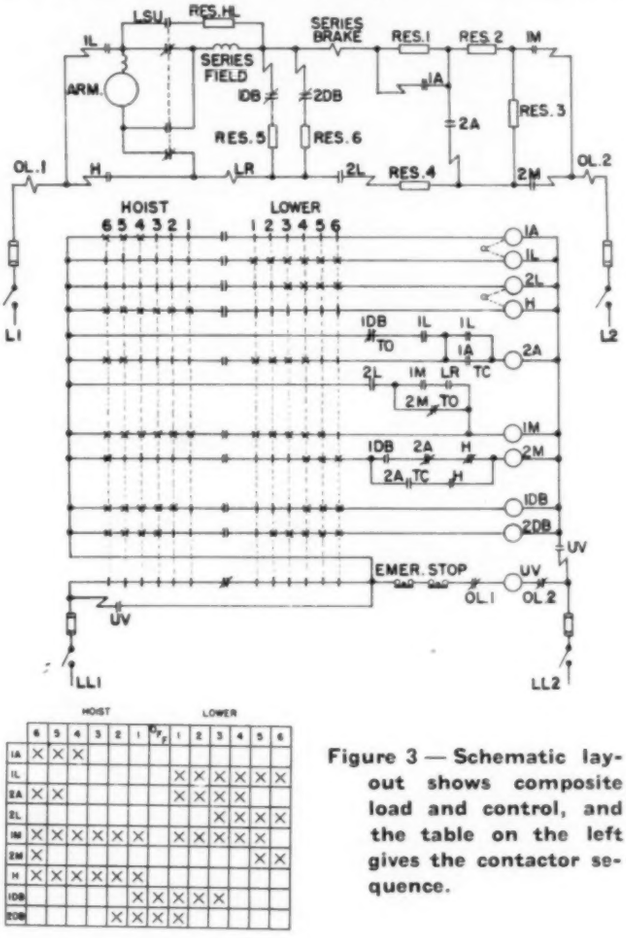


Figure 3 — Schematic layout shows composite load and control, and the table on the left gives the contactor sequence.

in speed 4 sufficiently long for the timer to have timed out.

The transfer to sixth speed is controlled automatically in two ways. A simple current relay LR closes its contacts if the armature current is in excess of a certain value, usually ¼ to ⅓ of full load current. A timer on 2M introduces a time delay before which the circuit cannot be "sampled" because the timer contacts bridge the contacts of LR for the duration of this timing period. If, after that delay, the current is below the predetermined value, the contacts of LR are open permitting 1M to drop out, inserting additional resistance in the field circuit. This gives high speed lowering with light load. It will be noted that the circuit is so arranged that reclosing of LR due to transient armature current at high speed will have no effect on operation since a normally open interlock on 1M prevents the reclosing of 1M, should LR reclose.

When returning to position 5, the field strength is increased causing a reduction in the lowering speed in much the same manner as is accomplished with a shunt field motor when the field is strengthened.

Returning to position 4 introduces the bridge circuit again. Notice that in this case, contactor 2A closes first, immediately followed by the opening of 2M. This sequencing causes a momentary strengthening of the field current since contactors 2A and 2M are closed at the same time, leaving only resistance 1 to limit the field current. As this field current increases, the armature tends to deliver more current into the resistor network so that when 2M opens, it actually interrupts less current than it would if the reverse sequencing were involved. Erosion and flashing at the contact tips is accordingly reduced.

Position 3 inserts the bridge circuit by closing one of the spring closed contactors further reducing the voltage across the armature and setting up the first element in the low voltage regenerative circuit.

Position 2 opens contactor 2L which brings the armature back to the potentiometer connection directly across the field.

Position 1 introduces the second spring closed contactor, and its resistor further reduces the voltage and speed of the armature.

It will be noted that in the "off" position, the armature, the field, and the two parallel resistor sections are connected in such a way as to cause regeneration if the spring closed brake should fail. That arrangement would limit the lowering speed of the hook so that damage to personnel, equipment and property is minimized.

CIRCUIT FEATURES

Close control—The use of two spring closed contactors provides for closer spacing of speeds in the low range. In lowering, the effect of opening one of these spring closed contactors is to insert extra resistance in the armature circuit. This permits the load to accelerate the hook so that when the master switch is moved to position 3 (establishing the bridge circuit), the motor speed has already increased, minimizing the transient current peak. The remaining spring closed contactor is then opened under a low current condition. This system of speed changes gives smooth operation and reduces contact tip maintenance.

Safety—The use of two spring enclosed contactors each having a resistor section gives extra safety in the dynamic lowering and regeneration circuit. Failure of both contactors or both resistors at the same time is much more remote than if a single current path were involved.

Stability—A weakened field characteristic of high speed lowering introduces instability and should not be used with heavy loads on the hook as a runaway condition of the motor may be developed. Relay LR is used to prevent such a connection. Test work with this con-

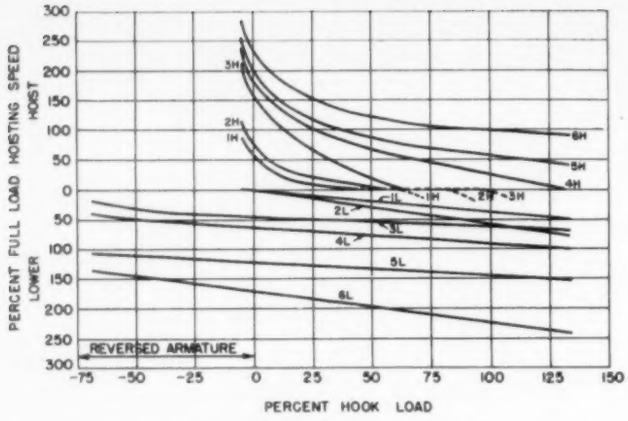


Figure 4 — Diagram gives speed-load curves for tests made on a 45-hp totally enclosed, series wound, d-c motor.

Figure 5 — The table shows the effect of changing resistor values on the speed points in the control.

	RES.1	RES.2	RES.3	RES.4	RES.5	RES.6
6H	○	○	○	○	○	○
5H	○	−	−	○	○	○
4H	○	−	○	○	○	○
3H	−	−	○	○	○	○
2H	−	−	○	○	○	+
1H	−	−	○	○	+	+
OFF	○	○	○	○	+	+
1L	+	+	+	○	+	+
2L	+	+	+	○	+	○
3L	+	+	+	−	+	○
4L	+	+	+	+	○	○
5L	+	+	○	+	○	○
6L	+	+	+	+	○	○

\+ SPEED INCREASES AS RESISTANCE INCREASES
− SPEED DECREASES AS RESISTANCE INCREASES
○ SPEED UNCHANGED AS RESISTANCE INCREASES

trol scheme shows that lowering speeds in excess of 200 per cent normal might be developed by field weakening with a full load on the hook and without reaching the point of instability. However, varying performance characteristics among motors of different manufacture and different efficiencies found in different hoist mechanisms make it advisable to maintain full field as a minimum whenever a heavy load is applied on the hook.

Positive brake release—The bridge circuit used for lowering is arranged so that heavy current is applied through the brake to assure positive opening on the first point, but this current is reduced in subsequent points so that the heating of the brake coil itself may not be excessive.

Resistor re-use—For the hoisting sequence the same resistors are brought into play, resulting in a first point current nearly that of full load and assuring positive action of the brake. Using two bridge circuits across the armature and field gives a low speed for taking up slack in the cable.

In point No. 2, one of the parallel paths across the armature and field is removed, and in point No. 3 a straight series connection is developed.

Points 4, 5 and 6 short out elements of resistance to give the increased speed. In point 5, this is accomplished by paralleling resistors 2 and 3.

TEST DATA

Detailed tests have been conducted in connection with this control scheme on a 45-hp totally enclosed, series wound d-c motor and load in excess of ten tons. Test data taken for the motor involved gives speed curves as shown in Figure 4.

In examining these speed curves it will be noticed that at least two low speeds are involved for light hook manipulation in the hoist direction, that at least three speeds below 100 per cent are involved for light hook lowering. As the load is increased, more effective use is made of the speed points. With 100 per cent load on

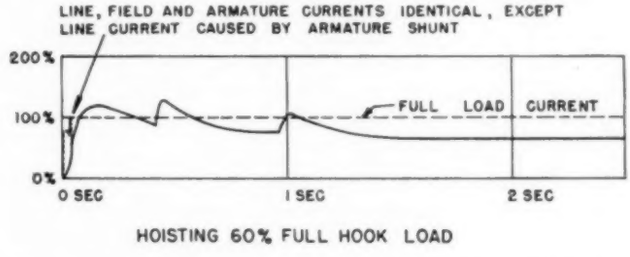
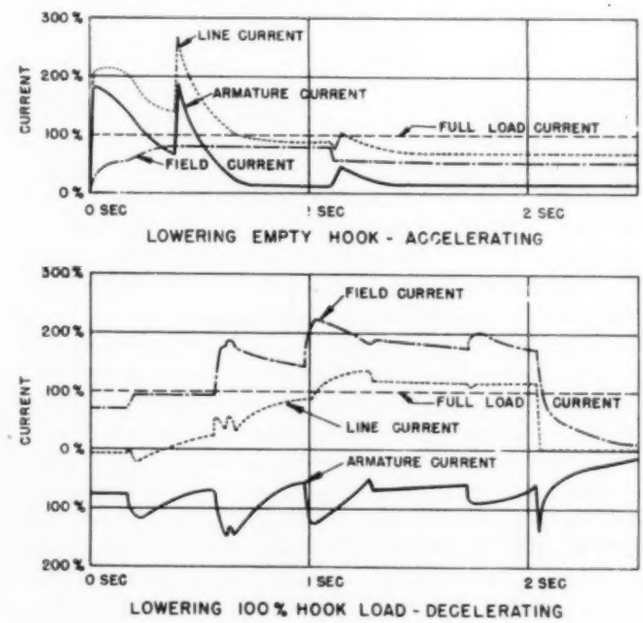


Figure 6 — This hoisting current curve was constructed from oscillograph data.

Figure 7 — These lowering current curves were constructed from oscillograph data.



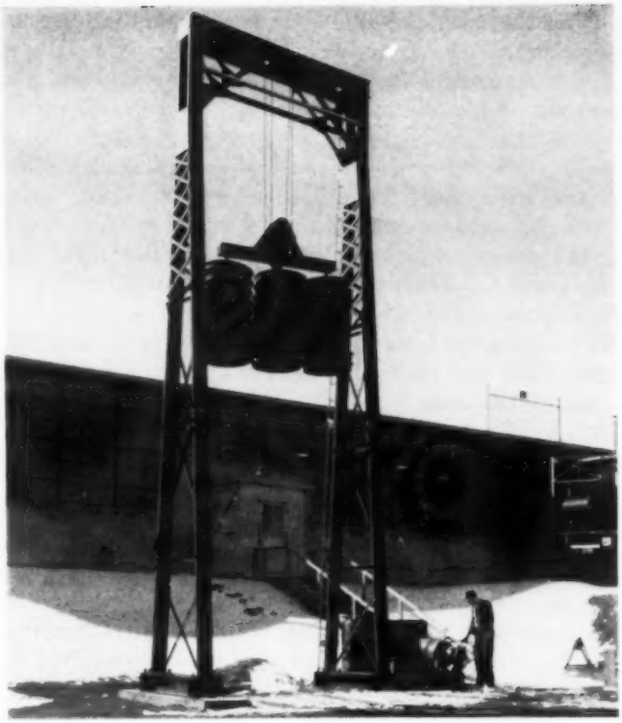


Figure 8 — The test hoisting rig shown was used to impose various loads and regenerative conditions on the motor.

the hook, at least three operating speeds are useful in the hoist direction.

In lowering, speed 2 is actually a transfer speed. At light loads, it may be approximately equal to lowering speed 1, with extremely heavy hook loads the No. 2 speed may be equal to speed 3. This then gives four operating speeds for heavy hook conditions below 100 per cent and a high speed heavy hook in excess of 100 per cent. 6L is intended for use with the light loads only.

A table showing the effect of varying the resistor values is shown in Figure 5. In general, resistor changes are not required as the bridging system controls the speed points rather closely, without regard to the motor characteristics. Resistors 5 and 6 may be unbalanced to secure different responses in hoisting and lowering on speeds 2 hoist and 2 lower. Resistor 4 is a peak limiter of low ohmic value which may be affected somewhat by the internal resistance of the armature of the motor. The slope of the lowering curves can be changed by changing resistor 4. Resistor 3 serves to introduce the weak field condition and may require some adjustment due to the saturation curve of the particular motor involved. The usual precautions should be taken to maintain secure terminals and tight connections to the resistor banks. A poor connection or a loosely mounted terminal may alter the speeds considerably.

The varying efficiencies to be found in hoist gear mechanisms require special interpretation when comparing the speed curves indicated for the test setup. The armature current for full load lowering was approximately one-half of that measured for the hoisting connection in the tests conducted. If another hoist mechanism were involved where the lowering current were appreciably in excess of one-half the hoisting current, it would have the effect of operating further out on the lowering curves. The opposite would be true of less efficient gear systems.

In the circuit under the discussion, contactors 1M and 2M relieve each other in duty cycle. While the relief is not on a 50/50 basis, it is such as to make them compare reasonably in duty cycle with other contactors a part of the system. No one contactor is permitted to heat excessively.

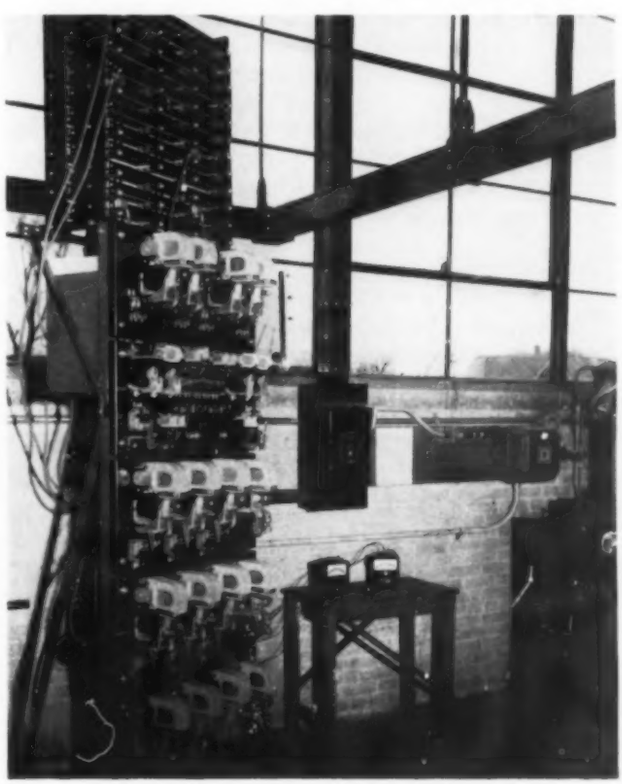
The hoist limit is the conventional type of load limit switch with self-contained resistor. Since this is a conventional unit, a discussion of it will not be included in this article.

With heavy loads slight drifting may be encountered in hoisting positions 1, 2 and 3. Drifting occurs in position 3 only if hook load is in excess of 100 per cent. Operators customarily pass through the low speed points quickly when hoisting heavy loads. Some like the drifting on the first lowering point when spotting a heavy load as it gives them an extremely low speed.

When decelerating the load, this controller has no automatic time delays in the circuit. This is considered the best of the possible arrangements even though the load might be decelerated too rapidly under abnormal conditions. In most cases, this is preferable to introducing a time delay in the response of the controller to the master switch. This is particularly true in lowering as the operator should maintain positive control in the event that something unforseen or unusual happens during his manipulation of the hoist.

A difficulty inherent with the use of a series brake is that it may reset in the case of high speed light hook

Figure 9 — A test panel was arranged with extra contactors and interlocks for setting up various circuits. The load circuit resistor is mounted above the controller, while the master, disconnect, power control and emergency push button are located on the right.



hoisting, where the load current may drop to a point that permits the series brake to reset. This condition can be avoided by proper selection of the brake.

Copies of the oscillograms indicating the current peak for various conditions when hoisting and lowering are shown in Figure 6 and Figure 7. The oscillograms show reasonably low commutating peaks and the absence of sharp or high peaks while decelerating the load in spite of the fact that rapid motion of the master switch was involved.

CONCLUSION

This circuit requires a minimum number of contactors to obtain six operating speeds. Low current transfer peaks within the controllers reduce contact replacements. Low accelerating and decelerating peaks in the motor armature minimize commutator and brush maintenance, and produce smooth action. Reuse of resistor sections for hoisting and lowering reduces resistor space requirements and provides greater reserve capacity by making the resistor less intermittent in design. Positive release of the series brake is assured by adequate current through its coil on the first point. Protection against unstable operation is provided by a simple current relay which prevents field weakenings at heavier loads. Speed points are chosen for ease in handling the full range of possible hoist loads. Safety is improved by the elimination of time delays when decelerating in lowering. Safety is improved by providing parallel contactors and resistors in the regeneration circuit greatly reducing possibility of failure in this circuit.

DISCUSSION

PRESENTED BY

JOHN A. CORTELLI, Chief Engineer, Clark Controller Co., Cleveland, Ohio

MARC de FERRANTI, Engineer, Materials Handling Div., General Electric Co., Schenectady, N. Y.

C. O. FRANKLIN, General Supervisor—Electric, Carnegie-Illinois Steel Corp., Munhall, Pa.

WILLIAM I. TURNER, Vice President and General Manager, Canadian Controller, Ltd., Toronto, Ontario, Canada

PAUL McKEEVER, Senior Electrical Engineer, Armco Steel Corp., Butler, Pa.

W. J. TUNNY, Superintendent, Electric Maintenance, Youngstown Sheet & Tube Co., East Chicago, Ind.

D. L. PETTIT, Supervising Controller Design Engineer, Square D Co., Milwaukee, Wis.

John A. Cortelli: The author has shown in his circuit the use of two spring closed DB contactors in parallel, instead of the usual single contactor, and these contactors are used as a motor shunt for two speed points in hoisting and the two slow speeds in the lowering direction. We have, and are still using, a single DB contactor to control the first speed in both hoisting and lowering and for the same reasons as pointed out by Mr. Pettit.

The slow motor shunt speed point to pick up slack is desirable on most crane hoists, however, there is one difficulty encountered with this connection and that is that if the operator runs into the limit switch while on this point, the brake remains energized and does not set to help stop the hook.

After the load has stopped traveling upward, it will again drift downward because the brake is not set. This condition is not too serious unless the speed is relatively high as the hook goes into the limit switch. A few crane users have specified that this speed point be omitted.

One other reason given for the use of this motor shunt connection is that it puts all of the current through the brake. How important this may be is sometimes questionable because series brakes are fast operating and will release on 40 per cent of full load current of the motor, and I believe that all modern hoist controllers will permit more than that amount of initial inrush. Also the contactor sequence can be arranged so that the initial inrush all goes through the brake by energizing the DB contactor after the line contactors have closed. I do not believe that a motor shunt on the first point is absolutely necessary.

We have on occasion used double DB contactors on hoist controllers usually for graduated dynamic braking where the contactors are deenergized in sequence for a quick stop. Another rather interesting application was on a bucket hoist on which the user wanted to open the bucket by letting it drift open. In this case we supplied a second DB contactor to furnish a "high" resistance dynamic braking loop, and by adjusting the resistor the bucket could drift open at any speed desired. The dynamic braking contactors were used in sequence to effect a graduated dynamic braking which was not only easier on the motor but also gave a quicker stop.

On lowering, much more important than the loop established by the DB contactors for speed control is a contactor or relay interlock sequence to make sure that a dynamic loop is always established before the DB contactors are opened.

On the subject of contactor erosion or contact wear, I believe that one will find that on a crane hoist the contactors handling the field currents will get the greatest abuse. Although it is important to keep commutating peaks on a motor within safe limits we cannot overlook the fact that field currents on lowering will exceed 200 per cent of full load current during transient peaks when decelerating from high speeds, regardless of the load on the hook. Because of the inductive nature of these field currents, the arcs on the contactor tips are vicious and will cause considerable burning and beading on the tips. A contactor not only must handle the arc but must have sufficient wipe to clean itself and break any weld on the tips that might be carried by a bead previously formed on the contactor.

Rating of contactors on a crane hoist must not only take into consideration the theoretical calculated running currents and peaks, but also an experience factor

on the frequency of the occurrence of the transient peaks. This experience factor is of material importance particularly on high speed hooks, short travels and particularly bad if the operator has a nervous master switch hand.

On automatic deceleration I agree with Mr. Pettit that it is not advisable. Good reliable circuit design which limits the transient peaks can avoid trouble with motors and contactors on deceleration from high speeds.

On the point of parallel use of resistors versus the use of straight series resistors, I believe that regardless of how one uses or reuses resistor sections, the important thing is the proper design of resistor banks so that they are built with sufficient capacity to handle, again, not only the calculated current conditions but also recognize the experience factor on occurrence of transient peaks.

In conclusion I would like to make some remarks not necessarily on d-c crane hoist controller design in general. The introduction of the new 600 series mill motors, with the single rating of one hour, has presented some problems to the controller manufacturer. We who build the control no longer can rely on the motor rating for the control design. Curves showing the "motor ability" on various duty cycles have been published, however, we do not know what "motor ability" the particular crane manufacturer may have used. For what hp do we design the control? What hp is to be shown on the controller nameplate? You, the user of the cranes, can no longer order a hoist controller by just giving us the motor hp rating or motor frame number. It will be necessary that complete application data be sent with the order if grief is to be avoided after installation. It is my opinion that on the nameplate of the motors, should be shown the one-half hour rating or ability and that this rating be continued in use for crane applications. This, I believe, would simplify matters for all concerned.

Marc de Ferranti: It is of particular interest to find that experimental work is being carried out to improve the performance of crane control and reduce the number of devices required. Anything which will reduce the number of devices required and still give safe and satisfactory operation of steel mill crane hoists will, I am certain, be well received by the operators' group in the steel mills.

Of particular interest is the fact that the author has used a six-point controller. For many years the use of five points on crane hoists has been popular, although there are advocates of a greater number of points. Recently there have been many who feel that three points on the hoist master switch are sufficient if the control circuit provides good characteristics on the low and the high speed points, both up and down. It would be helpful to hear some expression by the author and by the operating people on this point.

My interpretation of the author's presentation is that safe operation of a heavy load with the master switch on the sixth point, lowering, depends on the pickup of a relay (LR) and contactor 1M. For this as well as the other lowering points, it would be especially interesting to plot from experimental data the curve for high hook loads where armature reaction effects in the motor become more noticeable. This is desirable to indicate the range of load for which the lowering curves are stable. For some circuit connections and with full load on the hook, instability may occur at 200 per cent speed, whereas for other circuit connections and under the same conditions the motor would be stable at 800 per cent speed.

The ability to jog accurately with a controller of this type is, I believe, very important. In the spotting of loads it seems desirable that on the first, or at worst the second point of the master switch, it should be possible to jog any hook load from no load to full load in either the up or the down direction.

C. O. Franklin: In studying this new controller, the first thing I noted is the small number of contactors and interlocks compared with other designs. This should find favor with the maintenance man since there are fewer parts and "gadgets" to keep in stock and to give trouble. A comparison with six point hoist controllers of four other makes shows the following:

Make	Normally open contactors	Spring closed contactors	Control relays	Interlocks
Author's company	7	2	5	8
A	10	1	4	12
B	12	1	3	14
C	12	1	5	12
D (5 point)	9	1	5	16

The above tabulation does not list overload and undervoltage relays since all mill type controllers have an equal number of these devices.

Another feature of this controller is the small number of magnetic relays. Of the five listed above only one, the LR relay, is magnetic, the others being mechanically operated by the contactors through pneumatic timing devices.

The main features distinguishing this control scheme from other dynamic lowering schemes are the use of two spring closed contactors instead of one, and the use of the resistor network. Two spring closed contactors, as stated by the author, permit two creeping speeds in hoisting and provide a safety factor in case of failure of one of the contactors. However, it is questionable if two spring closed contactors are desirable from the maintenance standpoint, as some maintenance men claim they have twice as much trouble maintaining and adjusting spring closers as they do with normally open contactors.

The use of a resistor network makes efficient use of contactors, but it also complicates the circuit considerably. This may result in increased maintenance cost. The quantity of resistance used is, of course, not indicated in the schematic diagram, but it might be interesting to compare the number and size of boxes used in this controller with corresponding figures for competitive makes of equal horsepower and number of acceleration points.

In hoisting, two creeping points are provided by means of the spring closed contactors. Referring to the speed-load curves, we see that on the first point the motor stalls at about 40 per cent load, on the second point, at about 60 per cent load and on the third point at about 67 per cent load, leaving only the last three

points to accelerate heavier loads. Most controllers are arranged so that full load or nearly full load may be lifted on the second point, and this arrangement, it seems, would be preferred. It can be accomplished, of course, by reproportioning the resistors.

The author states that the sixth point lowering is intended for use with the light loads only. However, the crane operators do not know this and they will undoubtedly throw the master all the way over regardless of the load on the hook. If there is a tendency to overspeed and run away under these conditions, as seems to be the case from examination of the circuit, some corrective measures appear to be in order.

Automatic deceleration is not provided in this control scheme, the author stating that it is considered the best of the possible arrangements even though the load might be decelerated too rapidly under abnormal condition. This is a moot question and will no doubt be challenged by many operators as well as by other controller manufacturers.

William I. Turner: Over the past 15 years our company has built in Canada hundreds of dynamic lowering crane hoist controllers and we use a network system very similar to the one that is described. Credit for the original development of such a network, I believe, should be given to the late Jim Schnabel of Cleveland, who was one of the early originators of dynamic lowering controllers in the United States.

In Canada we are not bothered by the patent situation, allowing all the current to be put through the brake on the first point. We have, therefore, incorporated this in our design and it has added to our development of a good controller.

I agree entirely with the author that his use of resistors in the network system does give a very economical use of them, and I would expect his total weight of units to be as small as any competitive design on the market.

Like one other of your U. S. manufacturers, we also use a total of nine contactors on our controller, including one spring closed switch. We feel it is desirable to keep the number of spring closed switches to a minimum and time may raise this question with the author.

In our experience the crane operators either operate on the first two points or the last point of the master switch and we find that a five point controller is plenty for the vast majority of standard applications.

Paul McKeever: We have had need of a reliable dynamic lowering circuit on monorail hoists for some time. We have asked Mr. Pettit's company to give us a hoist control that he has described in his paper. It was a floor operated hoist controller using their heavy duty 50-amp contactors for use on a 5-hp, series, d-c motor. After they had set up a hoist and tried this circuit out, they shipped us this controller which we have had in service since March of 1948. The fact that he can take care of empty hook, partial load and full load with only nine contactors and eight interlocks has reduced the dynamic lowering control to its simplest form, which still has control of all the conditions I have just described.

I have, namely, monorail hoists for feeding coils to shearing, slitting and inspection lines. When we first started to use these hoists they were very good mechanically, but were very light electrically. As all of you know it takes electrical equipment designed for steel mill service to eliminate costly breakdowns. These hoists were rated at six tons and were motorized hoists and trolleys.

The equipment that gave us the most trouble was as follows:

1. Disc type brakes on hoist motor.
2. Control of the light duty machine tool type of construction.
3. Light duty resistors wound on ceramic bodies.
4. Push button pendant type of control.
5. Only dynamic braking we had occurred after hoist had gone into the safety limit switch.
6. Mechanical load brake which gave us some trouble, but not as much as the five preceding items.

To eliminate the above troubles we were able to develop a control composed of the following items that gives us very satisfactory service now.

1. Hoist motor has a series shoe brake.
2. Control now composed of 50-amp, heavy duty type contactors with dynamic lowering eliminating the mechanical load brake.
3. Nonbreakable high temperature alloy resistor banks.
4. Push button drum type pendant controllers, using cast aluminum cases and not bulky to handle.
5. A Youngstown type safety limit switch.

We found we had to take the initiative and develop mountings for the above items. After we had proven to the hoist builder these items could be mounted we could then get them mounted at the factory. In conclusion we believe the circuit Mr. Pettit has described along with his heavy duty type contactors has gone a long way in correcting our hoisting problems.

W. J. Tunny: When there is a loaded hook and the need for small increments of lowering speeds such as ladle, hot metal or billet yard cranes, the best control should be used. An improvement can be made on the control scheme which is indicated in Figure 3 of Pettit's talk by having the main, hoisting, and lowering contactor coils on a common lead which would be connected to a normally open contact in the master. The other side of contact would be connected to common side. This will help to prevent holding in on off point of these principal contactors in case of ground on master switch side of coils, or the holding in for any reason of the master contacts for these coils.

The use of fewer contactors is a marked improvement, as it not only reduces cost in making up boards, but makes a simpler control. It also reduces the size of the board thereby requiring less space in the control room. Space is a very important factor in a control cab, especially where the operator and the control is in the same cab.

The use of two DB contactors increases the factor of safety for dynamic braking, that is, if one DB should hold open for any reason the DB contactor which is in parallel would close the circuit for dynamic stopping.

D. L. Pettit: Mr. Cortelli's comments regarding the motor shunt connection and the limit switch contain a point that is well taken. However, this scheme has been used in the industry for quite a number of years and for

the most part, has been found to give the protection in the upper limit of travel for which it was intended. When it is considered that the hoist will not lift an appreciable load on the motor shunt points, it would take intentional manipulation by the operator to obtain such a condition with a heavy load.

Certain means are available for circumventing this condition. One method is to eliminate the shunt points completely in hoisting, and rely upon series resistance only for a slack cable and speed control. While this method does circumvent the problem described above, it does not give as good speed control for manipulating lighter loads.

Another method is to revise the connection scheme for the hoist limit switch to cause the opening of the motor shunt point when the limit is entered. It is necessary to add an additional trolley conductor to accomplish this result. Usually space and cost considerations for the additional trolley have influenced users to consider the present scheme adequate.

Of some importance is the consideration that the hoist limit, as placed in the load circuit, gives a connection which provides a dynamic braking condition for stopping the motor in the up direction and provides safety where the headroom allowed is small and the operator not too well trained. The use of this scheme depends somewhat upon the purpose which the user is trying to satisfy.

The pickup point of a series brake varies with its adjustment and conditions of wear within the brake itself. Some users attempt to make a brake and motor combination work even though there is some mismatch between them. These considerations of adjustment and a mismatch lead us to temper our considerations of release on 40 per cent of full load current and gives us our reason for using the shunt current as well as the motor current through the series brake to assure its prompt and positive release.

The network design in connection with the resistors will usually offer some space saving which, in turn, may be an important factor where space on a crane is limited for mounting these units. The amount of space saving varies somewhat with horsepower and the particular duty grouping that is involved. A variation may also be associated with the type or manufacture of the resistor involved.

I would like to add emphasis and concurrence to the remarks of Mr. Cortelli with regard to the final point which he has brought out. Controller design depends upon the motor ability involved in the application and whether we recognize it on the nameplate or in the published data makes little difference to the controller manufacturer. It is one of the factors that must be known in order to produce a satisfactory control for the application. This point cannot be too strongly emphasized. Failure to take it into consideration may completely misguide the controller manufacturer to the point where a controller is supplied entirely unsatisfactory for the application.

Mr. de Ferranti has brought up an interesting point regarding the number of points on the controller. It is our feeling that preference for the number of speed points will stem from the users rather than from control manufacturers because they are the ones who have the operating experience. Since five point controllers are more frequently specified, circuit requirements are satisfied in more cases by using a five point master with this circuit, allowing automatic acceleration into what is indicated for the sixth point. Where six speed points for all load conditions are required an additional contactor is added.

In pointing up Mr. de Ferranti's remark regarding the LR relay, it will be observed that contactor 1M was closed much earlier in the sequence and LR merely prevents it from opening and inserting resistance in the field circuit. LR may be considered a sampling device which after a time delay, samples the current condition in the armature circuit, and if it finds the current to be low as is associated with a light hook load, LR opens and permits a faster lowering speed.

Test data was not available to give the information Mr. de Ferranti has indicated desirable in connection with the questions concerning stability. However, these questions have been covered in other papers, one of which is entitled "Dynamic Lowering D.C. Hoist Control" and published in the proceedings of the A.I.E.E. Volume 67 for 1948.

Mr. Franklin's remarks are very interesting as they represent those of a user of extensive experience. These remarks seem to indicate a favorable reaction. There is one misunderstanding, however, which appears in his final remarks regarding the use of the sixth lowering point.

The sixth lowering point cannot be used even though the operator moves the master into the sixth point if the hook load exceeds a predetermined value. Relay LR locks out this connection preventing the crane hook from overspeeding in the downward direction.

I am thankful to Mr. Turner in his remarks for pointing out the saving offered by the network system in connection with the resistor. This saving has been borne out by his experience in building a network resistor.

The 50-amp contactors mentioned in Mr. McKeever's discussion are not recognized as standard in the heavy duty applications. However, where space factors have been important, a 50-amp contactor of construction similar to the remainder of the heavy duty line has been applied with good success.

It is again interesting to hear Mr. Tunny's discussion as it exhibits the user's point of view. The comment regarding the improvement in the control scheme is not clearly understood.

In connection with grounds in the system it is customary to connect all coils in common to the grounded side of the power supply and preferably make this side of the power supply negative in order to minimize the effect of corrosion within the coils. A ground in the master switch would then cause a fuse to open a circuit and introduce safe failure. It will be observed that the four contactors—1L, H, 1M and 2M—to which I believe Mr. Tunny is referring do not operate in pairs throughout the master sequence and, therefore, cannot be tied together. The number of contacts required in the master is well within the scope of more or less standard devices now available on the market and further reduction in the number of contacts could not be justified at the expense of adding relays or other auxiliary equipment.

METHODS OF SURVEYING STEEL PLANT WASTES

By A. H. ARBOGAST
Engineer of Combustion
and
J. E. GOLD
Experimental Engineer
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. . . . before one can eliminate the problem of stream pollution, one must determine how much and what kind of pollution is present . . . .

▲ AT the present time the steel industry is facing one of its most difficult technical and economic problems, stream pollution abatement. Stimulated by the steady growth and concentration of our population in cities located in the vicinity of our enormous industrial centers which have developed along many of the rivers of our country, both state and federal government have taken a hand in passing and enforcing legislation to abate and eliminate contamination of our various rivers.

In the enforcement of this legislation, a tremendous effort will be made to restore our natural waterways to a condition which will again permit natural biological development and growth, healthful physical indulgence, and unblemished industrial and navigational facilities.

By virtue of the administration code approved June 7, 1923, Pamphlet Law 498 and the amendments thereto and of Act approved June 22, 1937, Pamphlet Law 1987 as amended May 8, 1945 Pamphlet Law 435, the Pennsylvania State Sanitary Water Board is empowered to exercise certain powers and perform certain duties: "To preserve and improve the purity of the waters of the Commonwealth for the protection of public health, animal and aquatic life, and for industrial consumption, and recreation."

The Federal "Water Pollution Control Act" (Public Law 845) passed by the 80th Congress and approved June 30, 1948, places the responsibility for the enforcement of its pollution abatement regulations in the hands of the Surgeon General and the Federal Works Administration.

This law will not conflict with existing state controls —"it is hereby declared to be the policy of Congress to recognize, preserve and protect the primary responsibilities and rights of the states in controlling water pollution" (1)*, and should not stimulate either state or federal action against any steel plant so long as a policy of cooperation in pollution abatement activity satisfactory to the local state government is earnestly pursued to completion.

By the authority of this legislation, municipalities are provided with both technical and financial federal aid, while industry, although given some technical aid, is left primarily to its own technical and financial resources to solve its most complex and often times most costly problems which are causing stream pollution.

Stream pollution results from the discharge of any substance, solid or liquid, which causes, restrictions of the natural capacity and flow characteristics of a stream, or produces changes in chemical, biochemical and physical character of the stream, thereby altering natural conditions and making the water harmful of the normal development and growth of aquatic life and obnoxious for subsequent treatment and use as a domestic service water.

The solution of the many problems of industrial waste disposal which contribute to stream pollution requires ample laboratory facilities, together with an understanding of the various methods of chemical analysis, fluid measurement, interception, sedimentation, separation, neutralization and disposal as well as the functioning and general arrangement of available or improvisable equipment required to accomplish these processes.

Figure 1 — The general view of the river in the blast furnace section shows buildup of flue dirt in river channel.

* Numbers in parentheses refer to Bibliography at end of article.

Presented before AISE Philadelphia District Section Meeting, January 8, 1949

The organization of a force capable of handling pollution abatement activity depends on the size and diversity of production of the plant or corporation involved. [2] The assistance of a recognized consulting engineer is advised where the chemical engineering staff is limited or overburdened, but in most steel plants there is sufficient talent available to survey and efficiently handle the problems involved.

The recognition and estimation of pollution potential can be accomplished by a study of consumption or production figures pertaining thereto, but must be verified by qualitative and quantitative concentration determinations of the waste effluents. It is important to determine volumes of waste with accuracy, and that samples be collected in proportion to the rate of discharge of waste waters and in a manner which will insure a representative sample.

All plant processes involving waste disposal must be individually studied and classified, and evaluated according to pollution intensity. These findings will provide the basis necessary for the planning and scheduling of the installation of interception and treatment facilities. Where consumption figures are insufficient to estimate waste effluent concentrations, laboratory tests as prescribed in the ninth edition of "Standard Methods for the Examination of Water and Sewage," published by the American Public Health Association or other standard approved methods should be used. [3]

An industrial waste survey in a steel plant must be carefully planned and should proceed systematically

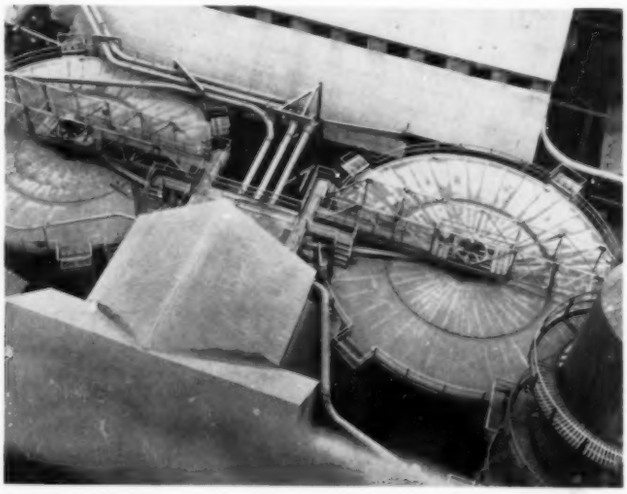


Figure 2 — A twin unit, balanced tray, thickener is installed for the separation of suspended settleable solids from blast furnace gas scrubber water.

to conclusion. Following is a list of the various departments and the probable sources of pollution agents to be investigated.

1. Quarries.
   a. Quarry sand.
   b. Silt washings.
2. Ore preparation.
   a. Separated gravel.
   b. Sand washings.
3. Blast furnaces.
   a. Washings from wet process and electric precipitators and drainage from water seals and gas lines, which together include the following ingredients in a fine state of suspension or solution: lime ore, lime, coke, cyanides.
   b. Waste lubricating oils from blowing engines and engine room floor washings.
   c. High temperature cooling and scrubber water effluents.
4. Open hearths.
   a. Steam condensate which may become mixed with fuel oil or tar due to leaking heating jacket on burners.
   b. Metallic oxides and the oxides of alkali earths removed by wet process scrubbers installed on stack exhausts for smoke abatement control.
5. Mills.
   a. Blooming and rolling mill effluents containing oil and grease residues and mill scale in cooling and roll spray water.
   b. Waste pickle liquors and pickle rinse water containing free sulphuric and hydrochloric acids, together with their respective iron salts.
   c. Galvanizing and electroplating liquors containing free hydrochloric, nitric, chromic and phosphoric acids, and the metallic salts of zinc, tin, nickel, copper, or cadmium.
   d. Mill engine condensates contaminated with steam cylinder oil.
   e. Paint spray systems and paint shop wastes in-

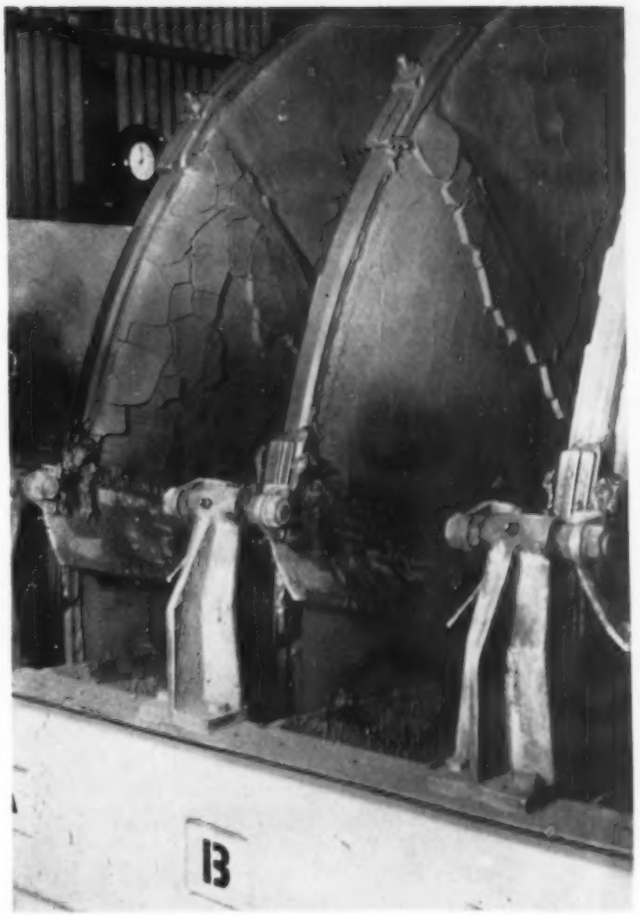


Figure 3 — Filter cake is removed from a rotary filter after the elimination of excess moisture.

cluding waste drying oils, solvents and hand or spray-brush washings.

6. Machine shop.
   a. Waste soluble cutting oils, lubricating oils and oily floor washings.
   b. Organic degreasing solvents and dissolved residues.
7. Forges.
   Steam condensate and spray effluents containing oil and grease residues and mill scales. Leakage or disposal from hydraulic systems.
8. By-product coke plants.
   a. Condensates, cooling waters and gas-line drainage contaminated with phenols or tar-acid residues, sulphur, cyanogen and ammonia derivatives.
   b. Waste caustic desulphurizer effluents containing sulphides and cyanides and ammonia derivatives.
   c. Waste iron oxide from desulphurizer boxes containing sulphur and cyanogen derivatives.
   d. Absorption oil residues.

The completed plant survey is the basis for action in industrial waste disposal and subsequent pollution abatement. The first step after the completion of the survey is the institution of laboratory research and pilot plant operation, if such projects have not preceded the actual survey procedure, for the determination of capacity and efficiency limits of preferred or expedient methods of treatment.

We should at this point review Article III, Section 308, Commonwealth of Pennsylvania (Pamphlet Law 1987) as approved and amended, to wit, "All plans, designs and relevant data for the erection and construction of treatment works by any person for the treatment of industrial wastes shall be submitted to the board for its approval before the works are constructed or erected."

When the survey and plans have been completed, a systematic program and calendar must be formulated which will establish a reasonably accurate schedule for construction, completion and subsequent operation. This point is of prime importance and should be mutually understood and agreed by both government and industrial agents during the preliminary conference proceedings in order to avoid misunderstanding and resultant controversy over certification of approval and subsequent enforcement.

Figure 4 — The general view of the river in the blast furnace section, one year after the installation of the blast furnace scrubber water separation equipment, compares favorably with Figure 1.

The question of acceptable numerical limits in parts per million of polluting substances is still to be settled for many of the industrial wastes. There are various yardsticks for the measurement of stream water quality, but pollution abatement laws, in general, have been formulated and approved in the general terms of "the protection of health, animal and aquatic life."

Much research work, both in the laboratory and through stream surveys has been done and is being continued for the purpose of determining the effects of various industrial wastes on biological life and development. W. B. Hart and others have made outstanding progress in their biological studies on the effect of industrial wastes on biological life and normal biological restoration in polluted waters. [4, 5, 6]

J. R. Hoffert, chief engineer, Department of Health, Commonwealth of Pennsylvania, made a clean case for both the people and industry in general in his paper on stream conservation given before this society in December 1944. [7]

At the present time we have few set limits to follow aside from the dictates of our own conscience.

1. Settleable solids should be given primary treatment for complete removal.
2. Acid discharge must be neutralized to a pH of 6.0 to 7.0.
3. Cyanides must be completely removed.
4. Iron must be completely removed. One of the provisions in a disposal permit recently granted reads as follows:

Special condition "E" directs that "sufficient lime shall be added to the spent acid pickle liquor to neutralize not only the free acid but also the potential acid in the form of hydrolyzable compounds." "The attention of the permittee is directed to the fact that special condition 'E' applies to sulphuric, muriatic, nitric and hydrofluoric, and all other acid wastes and also requires the complete removal of iron from the final effluent."

If 5 to 20 parts per million phenol is toxic to fish and aquatic life, and 3 parts per billion will produce objectionable tastes in treated drinking water, we can see where we stand on phenol limits. A tolerable phenol limit must be somewhere between 5 parts per million and 3 parts per billion, depending on the proximity of the plant to the next downstream municipal water works.

All sewage within a plant should be classified and separated into three systems:

1. Sanitary sewage.
   If a municipal system is available, sanitary sewage should be pumped to this system either raw or after primary treatment through septic tanks.
   At least one major steel plant utilizes municipal sanitary sewage effluent for process and cooling water.
2. Industrial wastes.
   This system should comprise only plant-process effluents with oil-bearing effluents treated separately from those requiring sedimentation, neutralization or other treatment.
3. Storm water.

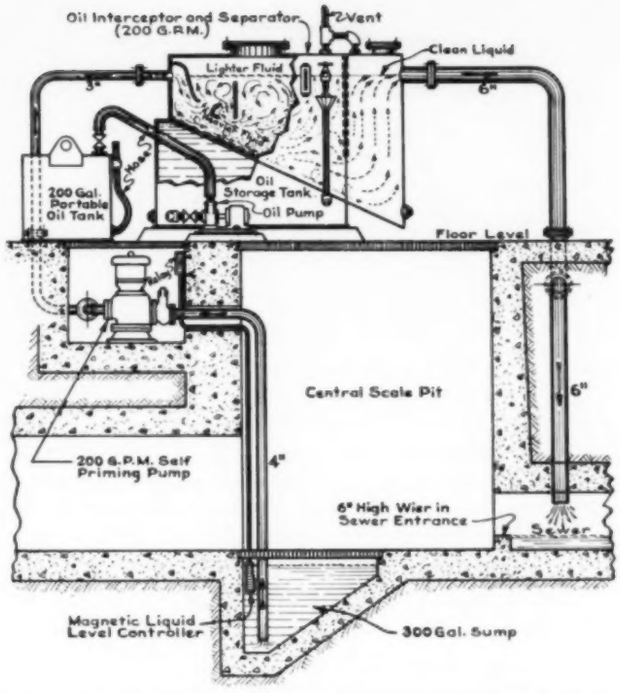


Figure 5 — Typical arrangement of interceptor installation for waste oil and sludge separation.

This system must be kept separate from all untreated sanitary or industrial effluents.

The interception and transportation of industrial effluents may be accomplished by gravity flow or pumping directly to the treatment plant if this plant is adjacent, or by storage in sumps or tanks with subsequent transportation by pumping, tank car or truck service.

The treatment methods involved include various types of sedimentation, separation, neutralization, oxidation and disposal.

Sedimentation may be accomplished by the use of lagoons, settling tanks or mechanical separators or thickeners. A lagoon may be defined as any open excavation either lined or open to direct seepage to the ground. Ground lagoons should be used only for seepage disposal and sufficient room must be available to extend the system when capacity limits become acute.

Settling tanks may be lined lagoons equipped with baffles, to permit decantation of effluents, and mechanical handling equipment, either crane or pump, to discharge the collected refuse or sediment.

Mechanical separators or thickeners are separating tanks equipped with rotating paddles and stationary baffles and weirs, to permit continual discharge of both separated sludge and clean supernatant effluent. These separators are also equipped with vacuum rotary filters for the purpose of producing a sludge sufficiently dry for handling and transportation. The thickeners illustrated in Figures 1, 2, 3 and 4 are installed in the blast furnace area of Bethlehem plant and are used for the separation and collection of solids from the gas scrubbers, consisting of iron ore, coke and lime. This installation, previously described by J. R. Hoffert and Christian L. Siebert, [8] is a splendid example of a simple, efficient and economic application of industrial waste recovery.

Separation is a common method of handling oily effluents. [9] The separating of simple oil in water pollution may be successfully accomplished by the use of well designed separators (Figures 5 and 6), or in baffled sumps or tanks in smaller installations. Suspended matter and volatile oils require additional precautions, and soluble oil emulsion necessitates very careful and skillful design of the separator, and are frequently difficult to handle [10].

The separation of a complex mixture of these elements would require facilities for acidulation for demulsification, neutralization and heating for removal of low volatile matter, oil separating chamber and floculating chamber for turbidity control.

Acid disposal includes the various processes of neutralization and regeneration. R. D. Hoak and C. J. Lewis have described many methods of acid neutralization, the most economic agents being calcite or limestone ($CaCO_3$) and hydrated lime [$Ca(OH)_2$]. [11, 12]

Figure 7 illustrates a continuous feed calcite system designed by A. L. Reidl for the continuous neutralization of mixed plating acids, including nitric, hydrochloric and phosphoric. This system utilizes granular calcite as the neutralizing agent and has been approved as acceptable to the local city sewage disposal system. [13]

Figure 8 illustrates a system designed for either batch or continuous neutralization and precipitation of waste hydrochloric acid pickle liquors. It includes a primary calcite neutralization sump for free acid neutralization together with a lime feeder and precipitation chamber which will introduce secondary neutralization as required for floculation or iron precipitates and to produce a clean effluent to the storm sewer.

Transportation to this system will include both gravity feed and tank truck services. The precipitated

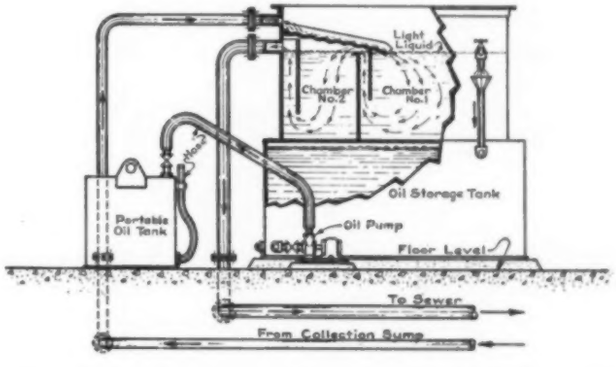
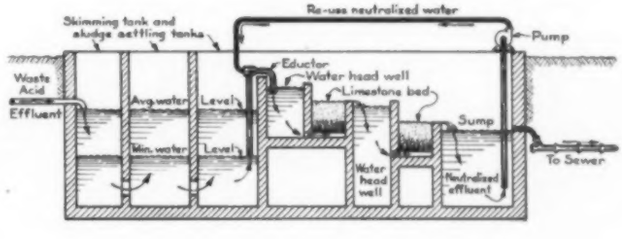


Figure 6 — Another arrangement of separator for waste oil and sludge separation.

Figure 7 — This typical arrangement of a calcite acid neutralizer was designed for plating acids.



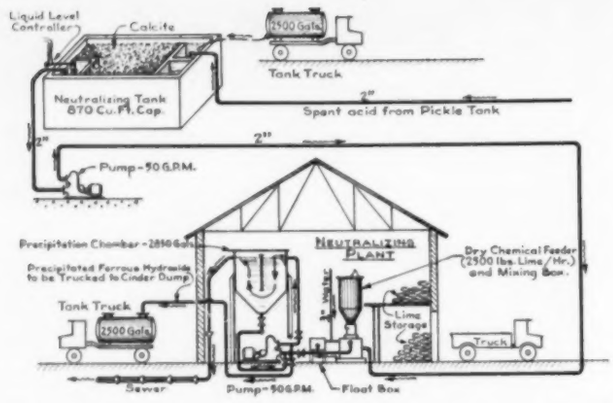


Figure 8 — Flow diagram for calcite and lime neutralization of spent muriatic acid.

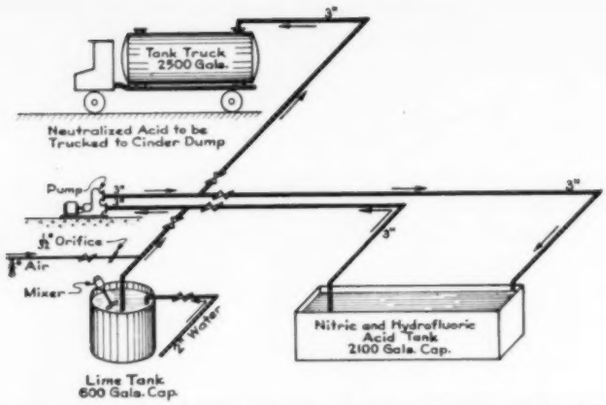


Figure 9 — Flow diagram for lime neutralization of spent nitric and hydrofluoric acids.

iron sludge will be removed by pump to tank truck and disposed of on a dry cinder dump.

Figure 9 illustrates a totally closed system for nitro-hydrofluoric acid pickle. Neutralization in this system is a batch type using hydrated lime which is mixed with water as a slurry in the lime mixing tank and then circulated by pumping directly into and through the acid pickle tank until thoroughly mixed and neutralized. After neutralization the mixture is transported in drums or tank truck to the cinder dump for disposal.

The neutralization of sulphuric acid comprises one of the most costly problems in industrial waste disposal. In the neutralization of these acid wastes calcite is only partially effective to pH 4.5 and together with hydrated lime for complete neutralization to pH 6.0 to 7.0 precipitates a mass of calcium sulphate and ferroso-ferric carbonates and hydroxides which presents a difficult and bulky disposal problem.

With the use of sulphuric acid as a pickling acid far exceeding all other acids in the average steel plant, its disposal as waste is the greatest economic problem in steel plant pollution abatement.

The research into this problem by the Mellon Institute has developed many methods for sulphuric acid neutralization and disposal, some of which show promise of fair economic recovery of the acid.

A regenerative process for sulphuric acid pickle has been perfected by one of the western steel companies and a full description of this process was recently published.

In a general plant survey it should be remembered that copperas or ferrous sulphate is one of the best chemicals available for floculation of suspended matter, demulsification of soluble oils and treatment of cyanides. (14) These reminders might be of material aid in the disposal of such sludges from pickle liquor wastes.

The systems involved in the treatment of by-product coke oven waste are quite complicated and require very careful process planning and estimation. (15, 16)

High concentrations of polluting materials will be found in by-product and ammonia still cooling water effluents and condensates, in storm water run-off from the by-product plant area, and in all coke gas line drainage drips.

Ammonia still wash water is usually pumped to the coke-quenching plant. Adequate sump capacity must be provided to contain this water together with drainage from the quenching operation.

A system for the collection, treatment and disposal of waste coke plant effluents must provide facilities for:

1. Separation or treatment, including the demulsification and separation of tar and oil emulsions.
2. Aeration or primary chemical treatment for phenol reduction.
3. Biological filtration for final phenol reduction.
4. Chlorination for final oxidation of phenol, cyanides and biological filtration residues and contaminants. (17, 18)

If sufficient space is available, lagoons can be planned to receive and dispose of these effluents after primary phenol reduction, but much precaution must be taken in design of facilities and process to eliminate all oils, tars or emulsions from the effluents before disposal to lagoons, and it must be kept in mind that a lagoon full of phenol-bearing waste is a constant source of possible ground water or stream contamination and should not be tolerated.

The ideal arrangement of a treatment plant for by-product coke plant industrial waste will return the treated effluents to the plant service system for re-use with lagoons available for emergency disposal service.

CONCLUSION

In this paper we have tried to outline the fundamentals of steel plant pollution abatement survey. Both state and federal legislation have placed the responsibility of stream pollution abatement on municipal and industrial operations. Some disposal operations will prove economically profitable, many others will have to be accepted as a production expense with major capital investment, maintenance and operating costs charged to production.

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DISCUSSION

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H. Gard Knox: As Messrs. Arbogast and Gold aptly say "stream pollution abatement is big business." For example one lone Philadelphia industrial plant turns out a heavier organic waste load than the total domestic sewage of the city. Fortunately this factory waste is now disposed of without recourse to the Delaware River.

Steel business is one of Pennsylvania's biggest industries and its wastes are varied and in many cases serious from the point of view of stream pollution. The usual steel mill wastes are well classified in the paper under discussion.

The paper presents a practical and logical method of tackling the pollution abatement problem of a steel plant and it so happens that the form of survey also fits in with the studies of the Sanitary Water Board in its present program of formulating effluent standards for industry.

Soon after its creation in 1923 the Sanitary Water Board grouped the streams of the Commonwealth into three classes as follows: (a) streams uncontaminated from any artificial source, hence generally fit for domestic water supply and fish life; (b) streams more or less polluted; (c) streams polluted so as to be unfit for public water supply and not capable of supporting fish life.

More recently, the board has defined three degrees of waste treatment based on common sewerage practice, namely primary, intermediate and complete. The streams of the state were then reclassified into those requiring one of the three degrees of effluent treatment or no treatment at all.

However indefinite or ambiguous these standards may seem to be as applied to a specific industrial situation differing widely in character from municipal sewage, they do furnish a foundation on which to build. The creation of more explicit standards is a long drawn out process upon which the board is presently engaged.

As studies progressed, the initial feeling was confirmed, that the adoption of one set of common standards for all industries would not be practicable. The present view is that a set of effluent standards will have to be adopted to each type of industry, and in some cases not only for each industry but sub-divisions thereof. The standards adopted must of course be based upon the practical aspect of the conditions requiring correction as well as upon something reasonable of attainment. With this in view, committees representing several industrial groups have been formed and after consultation between them and the Bureau of Sanitary Engineering upon the fundamentals of the problem, questionnaires have been sent out to the plants of the industry in order to gain firsthand information upon the plants, their products, methods of wastes disposal and the other factors from which practical requirements for waste disposal may be formulated by the board in cooperation with the industry. It is planned to continue this method of cooperative endeavor until all of the major industries have been covered and effluent standards appropriate to them have been promulgated by the board.

In the case of the milk industry, and oil and gas wells, effluent standards have been prepared by the Bureau of Sanitary Engineering and approved by the board and are about ready for promulgation. Wide investigations in the tanning and paper industry and pickling liquor studies in the steel industry are well advanced in the questionnaire stage.

Under either the present standards, or the new ones in preparation, it will be incumbent upon each plant to determine just what it must do in order to meet the requirements set up by the Sanitary Water Board. A detailed plant survey will, of course, be necessary and the features of such a survey are ably outlined in the present paper.

In this Commonwealth all authority to control state waters stems from legislative enactments. The laws now on the statute books are effective, but as in the case of most statutory law they are based upon the demands of conflicting interests resulting in wide compromises and sometimes in important loopholes in the final enactment.

The Sanitary Water Board is the agency vested with

the responsibility for administering our anti-pollution laws, and the Bureau of Sanitary Engineering of the Department of Health is the investigating and administrative arm of the board.

To live in this land of ours people must have clean water. To earn a living their factories and farms must have clean water—sometimes lots of it. Yet both the homes and the jobs dump their wastes to the river often regardless of the man downstream. The struggle amongst the water users grows as population goes up and water resources go down.

Pennsylvania's problem is further accentuated by the fact that its coal deposits represent one of the world's great fuel assets, but unfortunately the mining of coal usually results in the discharge of acid wastes or silt to neighboring streams. By the same token the mine country contains hills and streams ideal for the fisherman and camper and, of course, water works as a source of public water supply. How, therefore, are the water-rights and priorities of the home, the factory, the miner and the fisherman to be reconciled? The practical approach to a fair solution, as usual, involves the elements of give and take and is fraught with many difficult decisions.

The wastes of municipalities and of most industries can be treated so that before discharge their harmful effects are minimized for the fellow downstream. Likewise, water drawn from the river for home or factory use can be purified and safeguarded by such well known methods as filtration, softening, and chlorination. The feud between the coal miner and the angler is more difficult of solution because practical methods of acid mine waste treatment are not yet known and the fisherman, a fighting man, is loath to relegate even one of his streams for use as a lifeless drainage ditch. In this situation a veritable Solomon is needed.

Orders have gone out from the Sanitary Water Board to hundreds of industries requiring them to abate their pollution, or submit plans for waste treatment works. Orders for the actual construction of treatment works have been issued with considerable restraint initially because of shortages in labor and material and now because of the high construction costs. A drastic shortage of consulting engineers trained in methods of industrial waste treatment further handicaps progress.

The program of the board after the first months of rush is now much better crystalized and long range plans for cleaning up entire watersheds are now used as a basis for ordering abatement of wastes.

The Schuylkill River is, of course, the outstanding example in the Commonwealth wherein both state and federal funds are being used to rehabilitate a river which had been virtually destroyed as a useful waterway. As a vital part of the cleanup in the Schuylkill Basin, not only are municipalities and industries being directed to abate pollution, but the river channel is being cleaned out and restored to usefulness. We are glad to say that with two minor exceptions all discharges of anthracite silt to the Schuylkill have already ceased.

The clean-up on the Delaware River is also well underway, and is now highlighted by the planning and construction of the huge sewerage systems and treatment works in the city of Philadelphia. In the Pittsburgh area the Allegheny County Sanitary Authority is pushing an eighty million dollar project to serve both municipalities and industries.

Less spectacular progress is being made in other areas throughout the state and beneficial results on stream conditions are beginning to show.

In coming to grips with the task of pollution abatement a plant would do well to approach it from several directions. The first, obviously, is to check production methods to see if steps can be taken to reduce harmful discharges to the stream. It was found on a broad survey that the average milk can after dumping to the weigh tank still contained about four ounces of good milk which was a loss on the production end, and as waste in the wash water was a heavy contributor of B.O.D. to the stream. Milk cans in many plants are handled in thousands per day. Saving three ounces per can is easily accomplished and comes under the heading of "good housekeeping." In every industry there is opportunity for such savings.

The waste problem of some plants is made more difficult by discharging condenser circulating or other clean water into the same sewer with the pollutional material. The Sanitary Water Board does not recognize dilution of offensive plant effluents in this manner as pollution abatement.

Another group of wastes can be kept out of the plant drain by methods such as recirculation of water, thus forming a closed system. Many plants have profitably employed this technique.

Still other managements under pressure to eliminate waste discharges going up the chimney or down the sewer, have discovered by-products which can be sold at a profit.

There is no point in elaborating on the theme that abatement should start with waste reduction or elimination, leaving remedial treatment as a last resort.

It is needless to say the plant engineer will not be able to get to first base without the understanding support of the entire production staff.

The present paper might profitably contain a paragraph on the subject of cost studies. Every pollution abatement survey should contain cost data on the various schemes proposed. These studies in more cases than not are found to be incomplete, and if so, may be entirely misleading in reaching a sound decision. Cost of land, engineering, construction, depreciation, operation, maintenance, effect on production profit or loss and, last but not least, taxes should all be included. Every month we encounter faulty and incomplete estimates from which erroneous conclusions are bound to be drawn. This is a subject well worth attention.

Many of the problems facing industry in the abatement of its wastes are new and justify basic study and small scale field demonstrations before any company would be justified in making the expenditure necessary for a full sized treatment plant. On the other hand, there is a growing mass of information resulting from experimental work throughout the nation so that individual research is becoming less necessary. It is our hope that some of the money for research to be provided by the federal government will be allocated to the more fundamental nationwide problems involved in waste treatment, particularly in industry. Pennsyl-

vania is already maintaining several research projects and we hope this support will continue. Even on the assumption, however, that both federal and state research work continues there will still remain many problems of lesser scope in the laps of individual industries.

While there already exists a widespread understanding of the methods of treating domestic sewage there is no such established basis for dealing with industrial wastes in their infinite variety. By the same token consulting engineers lack background for recommending treatment methods in this field.

The Bureau of Sanitary Engineering, in Harrisburg, can modestly boast of a wide acquaintanceship with industrial problems, and its engineers will gladly confer on ways and means of tackling the treatment of factory wastes discharging to the waters of the Commonwealth.

The response of industry to the nuisance and expense incident to stream saving has been excellent. The Sanitary Water Board keenly appreciates the spirit in which the problem is being faced by industry and the board has shown every evidence of cooperating with plants which mean business yet need more time or, in some cases, even modification of the board's requirements. On the other hand the board is not without perception of the tactics of some firms where so called research and pilot plants have served to obtain delays beyond reason and have thereby penalized those who are playing the game on the level.

If in these remarks I have paid scant attention to the paper of Messrs. Arbogast and Gold it is because the paper is good. It is a worth-while contribution to the cause of clean streams which is here to stay and in which no segment of our population has a greater stake than industry and its workers.

E. W. Earhart: I would like to ask Mr. Arbogast if he has had any experience in chlorinating the water supply to improve sedimentation characteristics and to prevent pipe attack, attributable to slimes in unchlorinated water?

A. M. Quinn: In looking at the various diagrams presented by Mr. Arbogast and Mr. Gold, most of them showed a return to sewer. I was wondering if you were planning to make a collection basin or build a system of lagoons, or is it all going to go back into the river?

Clyde S. Cassels: I want to ask one question of Commander Knox. Of course, we are right on the Delaware and I had occasion today to take a look at the river. Does the state have a time table of any kind that could tell us when some visible improvement can be expected in the Delaware? We, ourselves, are engaged in a project and we know that several of our neighbors are. Will it be by 1950, '53, '58 or when?

C. R. Hand: There has been a lot of talk this evening on stream pollution. Has anything been done about pollution of underground water? We propose taking much of the waste now going into streams and disposing of it in dumps. How long is it going to be before these wastes percolate down to underground streams?

Many articles have been published on the lowering of the underground water level in various sections of the country. Around Sparrows Point the water table has gone down quite rapidly. I understand it is also going down out through the west.

Should we not be as much interested in keeping the underground water free of pollution as in seeing that the streams above ground are pure?

J. E. Gold: With reference to Mr. Earhart's question on the value of chlorination for the control of slime on cooling water, I assume it is perhaps a little off the subject matter, but we would enjoy saying that we have experienced fairly successful results in the control of slime in river cooling water, with moderately small dosages of chlorine. However, we do find that while chlorine is effective in reducing slimes, you nevertheless are still confronted with a problem of corrosion.

With reference to Mr. Quinn's question as to whether we shall return our treated effluents to the sewer or to the lagoons, and so on, I might point out that we are actually treating these wastes in organized treatment plants in the hope that we can discharge them directly to the stream without further treatment in the way of a lagoon. A lagoon is to our mind just another temporary measure of controlling your pollution, so, in conclusion, I might say we hope to discharge our effluents from our treatment plants directly to the sewer, and thence to the stream.

H. Gard Knox: Mr. Cassels asked whether the state has a time table in connection with the improvement of the Delaware?

As you know, the overall problem of the Delaware River is in the hands of INCODEL which is one of the interstate agencies controlling the pollution of our rivers. The Sanitary Water Board of Pennsylvania has a definite program for cleaning up the pollution of the Delaware River which is primarily contingent upon the cleanup of the Schuylkill River and the construction of new sewerage facilities in the city of Philadelphia. Both of these projects are now well advanced and should be completed within five years. Meanwhile, orders are being issued to all of the remaining industries and municipalities in the Delaware River Basin to abate their pollution by the time the two major projects are due for completion.

Another question: Mr. Hand asked what about the underground water?

We are as much interested in the underground water as we are in the streams above ground. The underground water is, of course, more difficult to control. We find that almost all forms of waste treatment tend to conserve water consumption and thus the construction of waste treatment facilities indirectly saves water.

In Pennsylvania we do not allow wastes to be discharged into old mines or into holes. A lot of people will pump water out of one hole, which they call a well, and are willing to discharge dirty wastes into another hole. Naturally, the dumping of wastes underground will, in many cases, pollute water supplies, particularly in some of the underground formations where horizontal fissures in the rock are extensively present. In some types of soil, lagoons used for the retention of waste waters will allow a certain amount of percolation into the soil under them. That is bad. There are many other soils where there is no percolation to the lower levels.

We are definitely interested in maintaining the water table in Pennsylvania and in preventing its pollution.

BLOOMING MILL OPERATIONS

at Keystone Steel & Wire Co.

By WILLIAM HERMAN
Superintendent of Rolling Mills
Keystone Steel & Wire Co.
Peoria, Illinois

. . . . that improvement continues after a mill is installed is well illustrated by the mill described, where production is now 2½ times the original figure . . . .

▲ THIS paper deals with the history and operation of an old mill built many years ago, and the only one of its kind in existence today. It is the sole survivor of two such mills, one built in 1902 and the other in 1917.

This type of mill has been operating for the past forty-seven years, but being located off the beaten track, it has received little attention, and few mill men are aware of its existence.

The basic principle involved, which differs from the conventional practice, lies in the fact that ingots are rolled directly to small billets in one and the same pair of rolls. It performs a double duty, that of a blooming mill and a four-stand billet mill. This is accomplished by the use of long roll bodies with a set of break down passes in one end, and a set of billet passes in the other.

It is a 35-in. two high reversing mill with a four-pass repeater and a looping floor attached. The repeater has an average diameter of 25 ft and the looping floor extends 70 ft from the center of the rolls. In one end of the roll the ingot is broken down in the conventional manner to a 3½ in. square. This square enters the first repeater pass and is repeated four times around the end of the roll and emerges as a 1¾ in. billet nearly 500 ft long. This is delivered to the billet shear by drag rolls where it is sheared to proper lengths for use in the rod mill.

The delivery speeds of all repeater passes being approximately the same, long loops are formed due to the elongation. At the peak of the rolling cycle, the bar is in three passes of the same roll at the same time and forms three loops on the looping floor which go bouncing over the turtle backs in a spectacular manner that is always viewed with great interest by the many visitors that enter the plant.

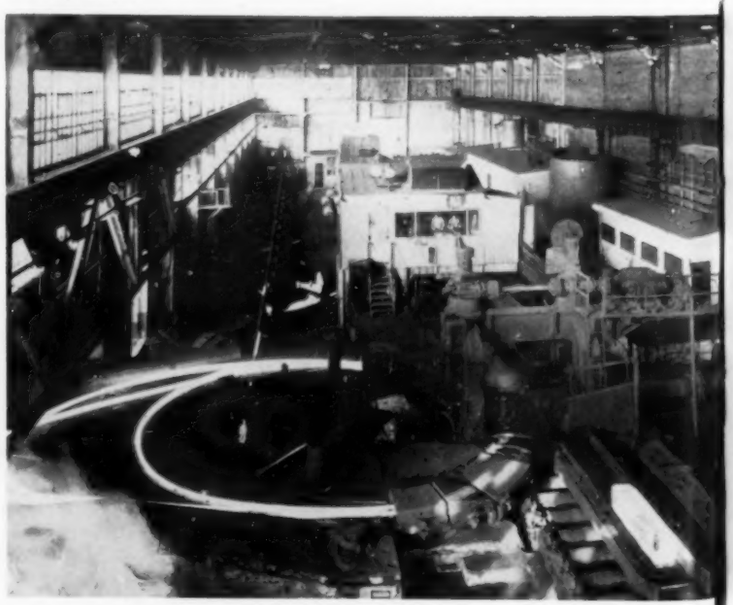
The idea for this type of mill was conceived by Mr. J. R. George who applied for a patent in 1902. The first mill was built that same year for the Grand Crossing Tack Co. in Chicago.

It was built to handle the production of two 50-ton open hearth furnaces and had an ingot heating capacity of 32 ingots, consisting of eight holes of four ingots each.

The mill was designed to roll 16 x 18 in. ingots directly to 1¾ in. billets.

The original mill was driven by a three cylinder steam engine 39⅜ in. x 39⅜ in. at 140 psi pressure and developed a maximum speed of 160 rpm. The engine was built by Ehrhardt and Siemans of Saarbrusken, Germany.

Figure 1 — This mill is the only one of its kind. The photograph of the mill shows bar going around the repeater.



Presented before AISE Annual Spring Conference, Baltimore, Md., May 2, 1949

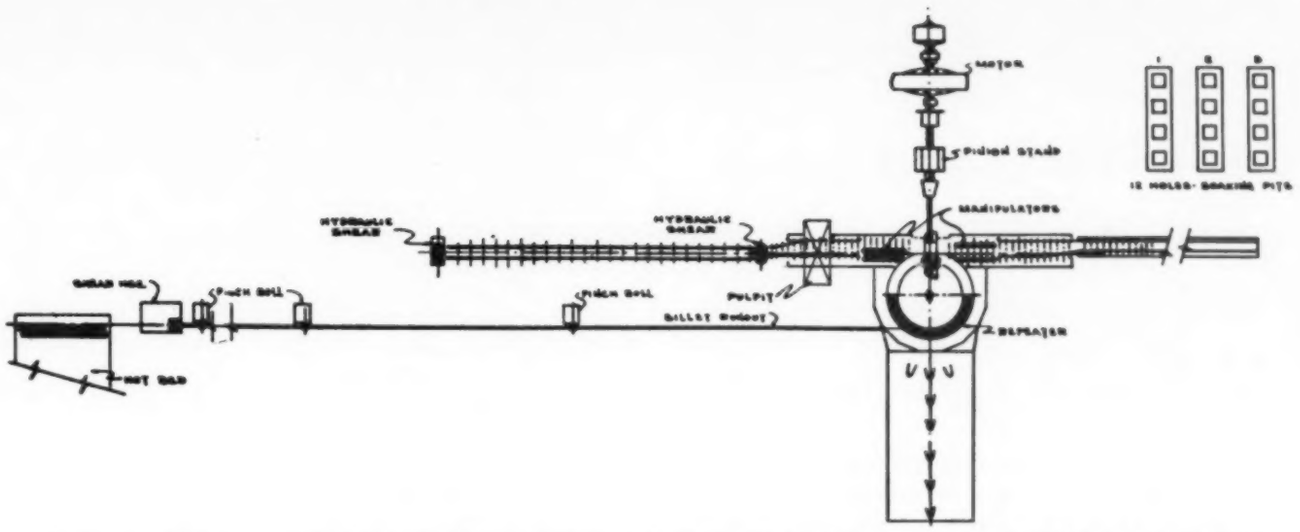


Figure 2 — This is a general layout of the Keystone mill from soaking pits at one end to billet shear and hot bed at the far end. Also seen are the repeater and looping floor, two hydraulic shears, the billet runout trough, drag rolls and billet shear located 670 ft from the center of the mill.

One of the lasting impressions created by a visit to this mill in 1918 was the terrific noise made by this engine. In approaching and departing from the plant the roar of this monster could be heard for miles.

The roll body was 28 x 96 in. and contained the following passes: a 21¼ in. bull head, a 12⅞ in. pass, a 6⅛ in. and a 3⅞ in. pass. In the billet end the conventional oval square passes were used to reduce the 3⅞ in. square to a 1¾ in. billet.

The bloom was trimmed on both ends by two hydraulic shears before entering the 3⅞ in. pass. The merry-go-round delivered the bar to drag rolls which conveyed it to a shear located 450 ft from the center of the mill. An open side shear cut the bar into billets and delivered them to a hot bed 24 x 30 ft. The mill was equipped with an electrically operated screw down and hydraulic top roll balance. The hydraulically operated side guard manipulator was the first of its type to be installed on a blooming mill.

The mill was operated on a single turn basis until 1916 when the plant was taken over by the Interstate Iron & Steel Co. The merry-go-round was in use until 1927 when an 8-stand 21 in. continuous billet mill was installed. By this time the open hearth capacity had been increased to eight larger furnaces, and it was no longer possible to handle the increased production with the old original setup. Therefore, the first mill passed out of the picture.

In 1917 another mill was built for Keystone Steel & Wire Co. at Peoria, Ill. This started operating in May of that year, just 32 years ago this month.

From 1917 to 1927 both mills were operating concurrently. Since 1927 the Keystone mill has been the only one of its kind.

As could be expected the second mill is an improvement over the first. It was designed to roll the output of three 75-ton open hearth furnaces.

The original soaking pit capacity was 12 holes of 6 ingots each or a total of 72 ingots sized 16 x 18 in. For many years the pits were fired with producer gas and later changed to fuel oil. Natural gas has been the fuel used for some years past. The ingots were rolled down to 1¾ in. billets in 25 passes, twenty-one passes were required to break the ingot down to a 3½ in. square, and four passes were taken on the repeater.

The mill is driven by a 2500-hp, d-c motor. It has electrically driven side guards, and screw down, and has a counterweighted top roll balance. Both ends of the 3½ x 5½ in. bar are cropped by hydraulic shears before entering the 3½ in. pass. The crops fall into pans which are removed when full and dumped into cars by the mill crane and are hauled to the scrap yard by the plant locomotives.

This is a one purpose mill. It was designed to roll 1¾ in. billets and that is all it did for 20 years. In the last 12 years it has rolled, or attempted to roll, various other shapes and sizes.

It has successfully rolled billets from 1¾ up to 2⅜ in. and 4 x 4 in. and 5 x 5 in. also some slabs for open hearth and soaking pit construction.

The practice in the open hearth is to use cast iron plates to cap rimmed steel ingots. When these were unobtainable, some 1 x 12 in. slabs were rolled for this purpose; on another occasion a few 1 7/16 in. billets were rolled for tapping bars.

During the war when shell steel was in great demand, an attempt was made to roll 3⅛ in. shell rounds. This high alloy shell steel was so tough, it refused to be pushed around, and it shoved a section of the merry-go-round off the foundation, and part of the foundation went with it. In other words, "the merry-go-round broke down."

Shell rounds were too much to expect from a mill of this type, so the project was abandoned. After the necessary repairs were made it was put back to rolling billets for the rod mill which it does very well and quite economically.

As the production of the open hearth increased, it became necessary to increase the production of the mill. One of the first things that was done to get more tonnage was to eliminate two long passes through the mill

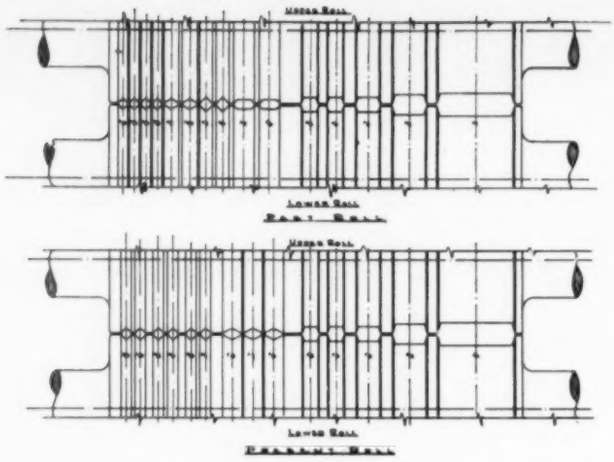


Figure 3 — The top drawing shows the pass layout used when repeating four times, to produce billets from 1¾ to 2 in. There are two sets of billet passes in each roll. When one set becomes worn, the guides are shifted to the second set, and when these are worn, the rolls are taken out and dressed. The bottom drawing shows the layout used when repeating twice to produce billet sizes from 2⅛ to 2⅜ in. These rolls have three diamonds and six finishing passes, with two finishing passes to each diamond. Each roll has three sets of passes which add to the life of the roll and reduces the number of roll changes. The switching arrangement is such that the bar from any one of the diamond passes can be entered into any one of the finishing passes.

by making one turn over on the back side. This feature alone added about 8 per cent to the production. The mill as originally designed had no provisions for turning a bar on the back side, and all turn overs had to be made on the front, or pulpit side.

The mechanism used to make this turn over is a simple affair constructed from parts found in the scrap pile. It consists of two locomotive cylinders, a few mechanical parts, and is located under the mill table. One cylinder operates a hold down hook on one side of the bar, and the other operates a piston that pushes up on the other side and turns it over. When this operation is completed the hook and piston both disappear under the table and are out of the way of the next bar that comes out of the mill. It is operated from the pulpit by an electrically operated steam valve controlled by the manipulator. It turns a 5½ in. square bar 70 ft long weighing about 6000 pounds.

The mill was built during the first World War and material and equipment were just as hard to obtain then as they were during the second war. When it came time to select a billet shear, the only thing available that would answer was an old punch press equipped with shear blades. This was installed and served the purpose well, as long as the mill was rolling 1¾ in. billets. About a year ago it was decided to roll larger billets. The billet shear was then replaced with a modern one of larger capacity.

The only lathe available at that time was a 36 in. engine lathe and that is still being used today with good results. It has proven to be an ideal piece of equipment for turning blooming mill rolls.

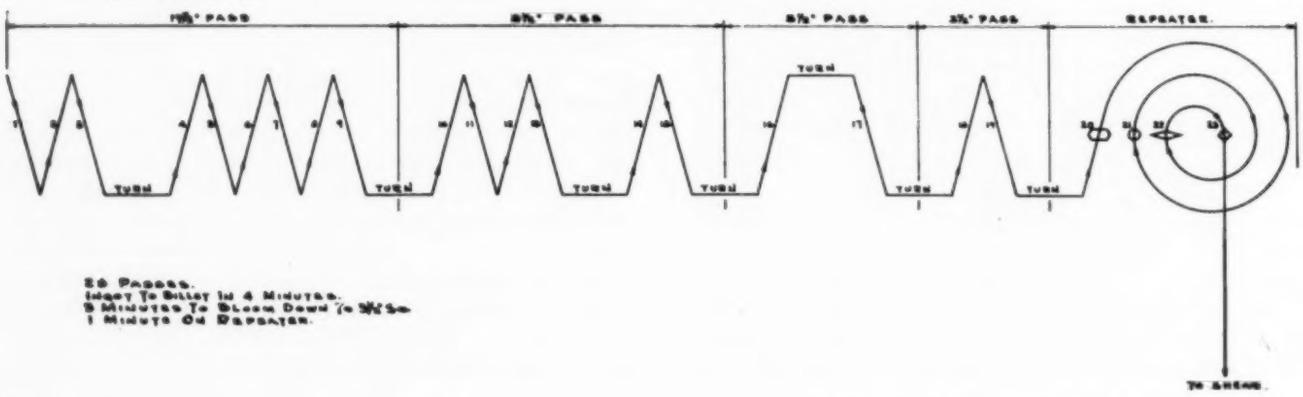
As the open hearth grew from three 75-ton furnaces to three 100-ton furnaces and later to 150 and now 175 tons each, the old mill has been able to take care of the entire output with time to spare. The open hearth has been the bottle neck for 32 years, but now with the advent of oxygen, compressed air, and improved furnace design, the mill is being crowded to the limit.

Several other changes were made to step up production. About four years ago the rotating regulator control was installed on the mill motors and screw down. This provided quicker reversals and shortened the rolling cycle considerably. Another increase was accomplished by rolling larger billets. The size of the ingots were also increased to 19½ x 19½ in. and the billets to 1⅞ in. and later to 2 in.

All of these changes together with added soaking pit capacity enabled the mill to keep pace with the open hearth.

The latest move in this regard was made a few months ago, when the four pass repeater was changed to a two pass unit. Certain changes made in the rod mill permitted the use of larger billets. It is now possible to roll 2 3/16 in. billets which can be done in two trips around the repeater instead of four. This shortened the rolling cycle still further and helped to balance the production. So by one device and another the mill has always been able to roll all the steel that the open hearth

Figure 4 — This shows all of the passes and turnovers, which consist of three passes and a turnover in the bullhead then 6 more and edge up to enter the 8 in. pass, then 4 passes and a turnover, and two more before edging up into the 5½ in. pass. One pass is taken through the 5½ in. pass then the bar is turned on the back side of the mill and given one more pass. It is then edged up and given two more passes in the 3½ in. pass. It is then turned and goes four times around the repeater for 23 passes in all to make billets from 1¾ to 2 in.



could produce, and supply the rod mill's demand for billets.

In 1918 the production amounted to approximately 400 tons a day. This grew to 600 tons a few years later. Then as the various changes were made it jumped to 800 and 900 tons per day. At the present time we frequently roll a thousand tons or more in twenty-four hours.

The soaking pit capacity at present consists of three rows of four holes each, or a total capacity of 112 ingots. The pits are fired by natural gas but can be switched to oil in emergencies.

The ingots are stripped in the soaking pit building by a 100-ton stripper crane and the mill is served by a 7½-ton pit crane. The ingot is reduced in 21 passes to a 2 3/16 in. billet or to a 1¾ in. billet in 23 passes. Twenty ingots have been rolled in one hour. This is three minutes per ingot and the maximum that can be rolled, requiring 2½ minutes to break down, and ½ minute on the repeater, or stating it another way—83 per cent of the time in breaking it down to a 3½ in. bar, and 17 per cent of the time on the repeater.

The mill scale is washed from under the mill tables and rolls by high pressure water to a sump on the outside of the building where it is removed by a locomotive crane with a clam shell bucket.

In the early days before the advent of heat treated alloy rolls, roll changes were frequent and required a lot of time. One of the first roll changes, in which the writer participated, it took 17 men 17 hours to do the job. Now it is done by 5 men in 5 hours. Being a lengthy job and a disagreeable one it was prolonged and put off as much as possible. Four or five days was the limit that rolls could be left in service. We were never in doubt about when this limit was reached. When an irate roller or heater from the rod mill would rush over to the bloomer to complain about the billets piling up in the furnace we knew that it was time to change rolls, and proceeded to do so at once.

The roll changes today are made less frequently, averaging from ten to fifteen days for four pass repeater work, and eighteen to twenty days for two pass rolling, and it might be said here without advice from the rod mill heater or roller.

The rolls weigh about 13 tons each when ready to go into the mill the first time (33½ x 96 in.). The discard diameter is approximately 29¼ in. The life of a roll is about 17 or 18 times in the mill with an average of ¼ in. taken off per dressing, in terms of tons of billets rolled it amounts to 150,000 to 175,000 tons. The two pass rolling should increase these figures by 50 per cent as there are 50 per cent more passes in the billet end than when repeating four times. By the same token it should reduce the number of roll changes 50 per cent.

The mill is operated by a crew of 17 men. In the soaking pits we have a heater, two crane men, two bottom makers, a stool cleaner, an ash wheeler, and a recorder. In the mill proper the crew consists of a roller, a manipulator, a motor operator, a guide man, two shearmen, a billet sorter and a maintenance man. In addition to this there is a mill foreman and one mill turner on the day turn only.

This brings to a close the story of a rare, old antique, that has kept pace with modern competition and is doing a bigger, and better job producing 2½ times as much as it did when first installed 32 years ago.

DISCUSSION

PRESENTED BY

W. T. MILLER, Superintendent, Lehigh Roll Shop, Bethlehem Steel Co., Bethlehem, Pa.

WILLIAM HERMAN, Superintendent of Rolling Mills, Keystone Steel & Wire Co., Peoria, Ill.

JAMES N. IMEL, Superintendent Rolling Mills, Jones and Laughlin Steel Corp., Pittsburgh Works, Pittsburgh, Pa.

W. T. Miller: What are the roll diameters, the working diameters and the rpm of the mill rolling the 1¾ in. billets? What is the ingot weight or what is the length of the 1¾ in. rolled billets?

What is the elapsed time from the moment the steel starts entering the roll pass leading to the first repeater trough until the tail end of the billet leaves the 1¾ in. roll pass, or the time required for a complete repeating cycle?

William Herman: With maximum roll diameters of 33½ in. and the mill operating at the top speed of 140 rpm, the delivery speed will be approximately 1200 fpm.

The ingot weighs around 6000 lb for killed steel and about 5600 lb for rimmed steel. The length of the 1¾ in. billet, after cropping will vary in length from 480 to 520 ft depending on the kind of steel rolled.

At the time, we were rolling 1¾ in. billets, it required four minutes to roll an ingot, three minutes to break down to a 3½ square and one minute to go around the repeater. The mill has since been speeded up and the time required now would be about 20 per cent less than that.

James N. Imel: I would like to ask Mr. Herman how he controls the loop in the last three passes from either looping up or stretching; is that done by roll diameters?

William Herman: There does not seem to be any trouble with the loop. We simply send it around through guides from the front side of the mill to the back side of the mill. The diamonds are twisted up and the loops seem to take care of themselves very well. There is a low spot in one side of the repeater and it jumps out at the lowest point and travels down between sideguard rails, and we have very little trouble in controlling the loop. Sometimes the bar does not enter on the front side, due to improper twisting of the guide, the diamond, especially; the only one we do twist is the diamond, but when that fails to enter the front side, we have a cable with tongs on one end and a loop on the other, we throw the tongs over the bar and the loop over a pin on the sideguard and attempt to pull it in with the sideguard. If this fails, we take the torch and burn it off on the back side of the mill, take a wrench, put more twist in the bar and send it around once more. This usually is effective. When this fails, we simply have a cobble on our hands and use the torch, cut it up, and drag it out.

PROBLEMS IN SPEEDING-UP STRIP MILLS

By F. MOHLER
President
Patterson-Emerson-Comstock, Inc.
Pittsburgh, Pa.

. . . . progress in speeding-up strip mills has been largely dependent on reducing inertia, both mechanical and electrical . . . .

▲ IN a span of less than twenty years, strip mills running 250 fpm have been developed to mills which will run a mile-a-minute, and this is indeed a page in the history of progress in the steel industry. Electrically speaking, most of the problems in the speed-up could be expressed in one word, "inertia." Inertia can be divided into two general classes—mechanical and electrical. Motors of ever decreasing inertia or WR^2 and yet with better and better electrical characteristics have been a continuous challenge to the machine designer. Control, which is the nervous system that coordinates the conglomeration of machines in the modern mill, has caused more engineers to solve many problems. Fundamental study i[illegible] resulted in such advances as the rototrol, the regulex, the amplidyne, and the tensiometer.

The desire for lower inertia motors has been one of the greatest spurs to the development of better motors for all purposes. The torque and likewise the WR^2 of a motor is essentially proportional to the diameter squared times the length of its armature. It is obvious therefore that the easiest way to reduce inertia is to reduce the diameter and lengthen the armature—in other words build a longer motor. That sounds simple, but the longer the armature, the greater the shaft deflection, the more difficult the ventilation, and most serious, the poorer the commutation, because of the increase in reactance of the winding. Thus the machine designer is in a continual dilemma as to how far to go before he gets into trouble.

The operators do not care too much for a rubber shaft, a roasted motor or arc lights on your commutators.

Deflection varies as the cube of the span and approximately a thousand cubic feet of air must be forced through an armature for each kilowatt loss. In addition the longer the armature the higher will be the resistance and the greater the loss.

Deflection and ventilation have been pretty well solved by the development of fluted shaft construction and by rating motors on a forced-ventilated rather than on an open or self-ventilated basis. The fluted shaft consists essentially of an oversize shaft with slots milled into it to allow the air to enter the inside of the armature. The punchings are pressed directly on the shaft, and it is of course impossible to remove the shaft without disturbing the armature.

In addition, shorter bearings, thrust collars and commutators which require less space have been developed. Further developments along these lines are continuing, but it is obvious that, irrespective of commutation, there is a definite limit to the minimum diameter of a given machine rating.

Some of the least talked about, but, probably the most outstanding developments have been made in connection with commutation, in this battle against inertia. The proper distribution of flux in a machine is of course the fundamental of good commutation. It is not too long ago that such studies were so tedious and long drawn out that the design of main field poles, commutating poles, and compensating windings was pretty much a matter of guess work. Methods have been developed which have very materially speeded up these studies, and these have contributed in no small way to better commutation and the building of longer motors. Considerable research has taken place in connection with the design of brushes and brush holders, and has also resulted in materially better commutation. These studies and researches are continuing, and we may look forward to even greater improvements in the future. Thus the speeding up of strip mills has literally forced the design of better motors.

Why all this emphasis on inertia? Simply because no one has found a method of handling strip except in coils and no one has devised a means of threading a mill at full speed. Thus the mill must be accelerated at the

beginning of each coil, and decelerated at the end of each coil. Even if these developments came true, you would still want low inertia drives, because strip will break, and it is essential to stop the mill as quickly as possible to prevent roll damage.

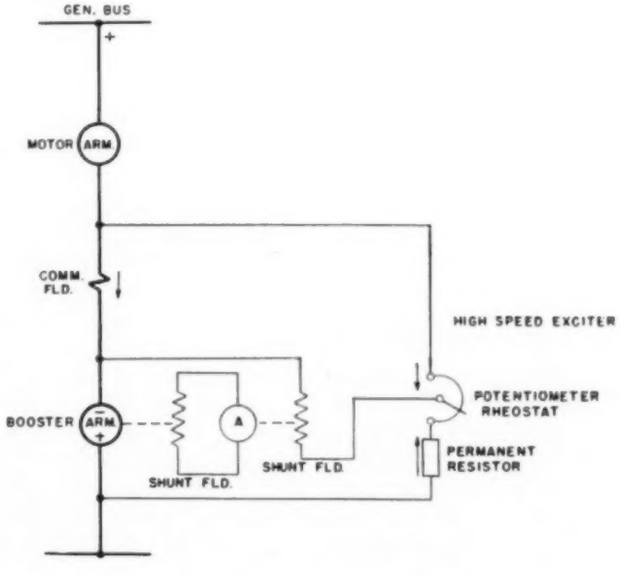
Operators are interested in good gage, a minimum of breakage, and a maximum of production. Several papers have been presented on gage and tension control, and this paper will not go into a repetition of all the ramifications of these subjects. What it will cover is the conception of the fundamentals involved, and how to lay out a high speed mill which will give the desired results.

It is sound practice to lay out the drives as fundamentally correct as possible within the bounds of sound economics, and in relying on control only for the refinements.

The most important factor in obtaining good gage is that all motors maintain exactly the same speed relationship, so that tensions increase or decrease as the gage tends to run heavy, or light, respectively. This is a so-called "hard" mill. To obtain such operation, the ideal motors should be designed so they all have the same percentage armature circuit resistance, require the same percentage accelerating current (including the WR^2 of the mill), operate at the same percentage load current, and have almost flat speed regulation. These conditions, of course, are impractical to obtain on a 100 per cent basis, but they should be approached as nearly as possible, as will be explained later.

Since they cannot be met 100 per cent, we turn to ohmic drop compensation, which has been thoroughly discussed before the Association of Iron and Steel Engineers. However, for stable and safe mill operation, the motors should have 1 to 2 per cent speed drop from no load to full load when the armature circuit resistance is 100 per cent compensated. This can best be obtained in the motor design by using a slightly offset pole face winding. When this inherent machine design is used, the percentage speed drop is almost independent of armature voltage or motor speed, and it is not necessary to rely on any fancy control. The ohmic drop compensation control has only one job to do, to apply a voltage to the armature circuit equal or proportional to its RI drop, irrespective of the main generator voltage, motor field strength, motor speed, etc. This control scheme is very simple, as can be seen by Figure 1. A portion of the booster voltage as determined by the setting of the potentiometer rheostat is opposed by the drop across the commutating field of the motor, and the difference is applied to the field of a high speed and high amplification exciter. This exciter in turn excites the field of the booster generator. Polarities are such that if the booster voltage is low, the drop across the motor commutating field will cause the exciter, and therefore the booster voltage, to rise to the proper value, and vice versa. Thus, the potentiometer rheostat can be calibrated in percentage RI compensation.

Figure 1 — The booster generator control scheme is very simple.



The most important factor in obtaining a minimum of strip breakage is just the opposite to that for obtaining good gage. In other words, the drives should have a greater and greater speed drop with load, depending upon the tendency for the strip to break. This can readily be done by decreasing the percentage RI compensation. This is a so-called soft mill. With the scheme just shown it is easy to arrange the control to simultaneously raise or lower the RI compensation of all drives without disturbing the relative adjustments.

Although theoretically the RI compensation will compensate for variations in load currents and accelerating currents, it must be remembered that the degree of perfection obtained is determined by the battle against electrical inertia. If you will stop to analyze the circuits and machines, you will find a multitude of varying time constants in series. The faster the mill, the more important to reduce the electrical inertia and give the control less to do. Thus there is the desire for low and balanced accelerating currents, as well as the selection of the proper size motor for each drive. In addition, the range of products to be rolled on a given mill should be kept to a minimum.

The most important factor in production, is rapid acceleration without strip breakage. This does not mean rapid deceleration, because the slower the rate of deceleration, the faster the mill will be cleared. It is possible to control deceleration so that not only is the mill cleared faster, but so that each stand will be running at its maximum speed for efficient threading. I have seen some mills that were operating as much as one-third of the time at threading speed.

Bearing in mind that most "off" gage and breakage occurs during acceleration and deceleration, and that a considerable portion of the operating time is spent in clearing and threading the mill, it is obvious that the greatest single factor affecting all is the size of the coil. For every size coil there is an optimum maximum operating speed from the standpoint of investment. In many instances you could better afford to spend money for obtaining larger coils than in speeding up the mill.

Let us briefly examine the selection of drives for a hypothetical mill. Let us assume a five-stand, tandem tin plate mill 42 in. wide with a so-called nominal operating speed of 4000 fpm. Now for the sake of simplicity let us consider only the so-called maximum and minimum schedules which are to be rolled. By maximum is

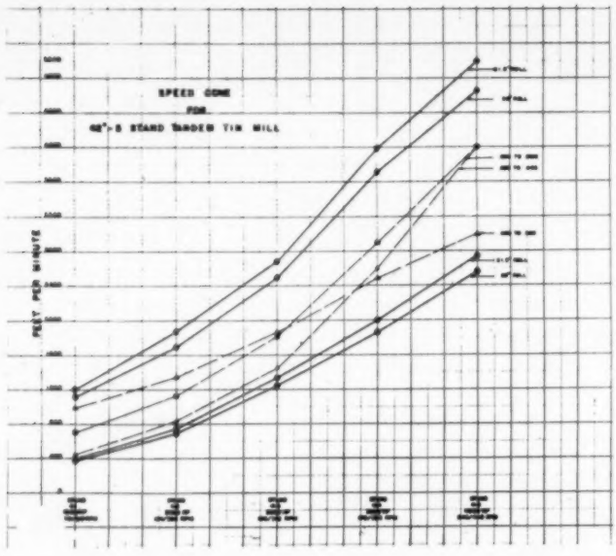


Figure 2 — The speed cone for the 42 in. 5-stand, tandem tin plate mill is initially computed for the production schedules to be rolled.

meant the maximum elongation, or rolling from the thickest to the thinnest. By minimum is meant the minimum elongation, or rolling from the thickest initial to the thickest final gage. Let us say that these schedules are respectively, 0.095 to 0.006 in. or an elongation of 16 to 1, and 0.095 to 0.025 in. or an elongation of 3.8 to 1. It is desired to roll the former at 4000 fpm and the latter at 3000 fpm. Using proven reductions established by good rolling practice, we can calculate the delivery speed of each stand, and plot of these speeds is shown by the 0.006 and 0.025 curves of Figure 2.

This determines pretty well the spread of the speed cone. From the 0.006 curve and allowing approximately 10 per cent for operating adjustment beyond that required for roll wear, we can quickly establish the base speeds of stands No. 1, 2 and 3. This may seem a little close, but it must be borne in mind there is relatively a small production required of 0.006 in. and the high production schedules of 0.008 in. to 0.010 in. would lie well above this.

The 0.006 schedule also determines the top speed of stand No. 5, and it will be noted that approximately 25 per cent is allowed for operating adjustment and roll wear. This leeway is most important on stand No. 5 because gage is usually controlled by adjusting its speed.

The 0.025 schedule determines the base speed of stand No. 5 and the top speed of stand No. 1. It will be noted that stand No. 1 requires a 3 to 1 speed range motor. However, this is usually not serious because No. 1 stand motor is always lower in hp, and its speed and accelerating currents are rather low. Having established the base speed of stand No. 2 motor, usually a 2½ to 1 speed range motor works out to advantage. Similarly stand No. 3 is usually selected as a 2 to 1 speed range motor. Experience has proven that when the foregoing steps are taken, a 2 to 1 or less speed range motor can be selected for stand No. 4 with speeds which will give a fairly smooth speed curve. For a complete analysis, of course, all desired schedules should be plotted in to be sure there are no bottlenecks.

Having established the desired speed cone, the horsepower required for each of the schedules can be calculated from test load curves by methods already presented to the AISE. See Table I. In this particular case, based on the 0.006 and 0.025 schedules, calculations show that a 1500-hp is required for No. 1, 2500-hp motors for stands No. 2, 3, and 4, and a 4000-hp motor for stand No. 5. Both schedules are based on rolling strip 32 in. wide. However, it was desirable to roll the 0.025 schedule up to 36 in. wide, and therefore 3000-hp motors were selected for stands No. 2, 3 and 4. See Table II.

Note particularly how radically tension affects the calculation, especially No. 1 and No. 5 stands. On schedule A, tension reduced the load on No. 1 stand by 405 hp and increased it on No. 5 by 720 hp. On schedule B, tension decreased the load on No. 1 by 1300 hp and increased it on No. 5 by 2025 hp. These calculations were based on the following tensions which have been found to be good average practical values.

Between stands 1 and 2—18000 psi.
Between stands 2 and 3—20000 psi.
Between stands 3 and 4—28000 psi.
Between stands 4 and 5—40000 psi.
Between stands 5 and reel—8000 psi.

Now comes the designer's headache. First, he checks the highest speed at which he can build a particular motor and then calculates the WR^2. If too high, he lowers the speed and continues to do so until he gets the accelerating current down to a reasonable value. The faster the stand, the more difficult. In order to get the WR^2 low enough, the design may pass successively from a single armature with reduction gear, to a single armature direct connected drive, to a double armature direct drive, to a triple armature direct drive, to a single armature twin-drive, to a double armature twin drive. (Figure 3).

It seems a shame to add inertia by step-up gears, but the overall accelerating current is reduced, and so far, other alternatives do not seem feasible. One of these is a direct connected twin drive similar to the blooming mill arrangement. However, the necessary angularity of the spindles operating at such high speeds seems almost certain to be a continual source of trouble and maintenance. It has also been suggested that twin drives be applied to the back up rolls. This would allow the use of slower speed motors because the relative diameters of the back up roll and work roll would take the place of a step-up gear. Furthermore, the increased vertical spacing would allow the motors to be placed so as to eliminate any spindle angularity except that required for roll wear. These spindles would run slower by the ratio of work roll to back-up roll diameters. No one has had quite the nerve, however, for fear of slippage between back-up and work roll. This arrangement has a good possibility of being successful, and will make the best overall drive. Another method is that of driving a single work roll, and this was tried experimentally in one case by disconnecting one spindle on a conventional drive, but slippage between the strip and work roll was the result and this scheme was discarded.

I have seen as many as thirty drives laid out in order to arrive at the best overall solution. Table III shows the drives finally selected for the hypothetical mill

TABLE I

SCHEDULE A

Pass No.	Thickness	Per cent reduction	Rolling hp	Fpm	Forward tension		Back tension Hp (+)	Net hp
					Lb	Hp (—)		
0	0.095	..	.....	.....	.....	.....	.....	.....
1	0.052	45	1560	446	30000	405	0	1155
2	0.028	46	2020	830	18000	450	405	1975
3	0.016	44	2080	1450	14350	630	450	1900
4	0.009	43	2300	2600	115000	905	630	2075
5	0.006	33	1890	4000	1485	185	905	2610

SCHEDULE B

0	0.095	..	.....	.....	.....	.....	.....	.....
1	0.075	21	1820	995	43250	1300	0	520
2	0.055	27	2720	1350	35200	1440	1300	2580
3	0.040	27.5	3110	1865	35800	2020	1440	2530
4	0.030	25	3130	2485	38400	2800	2020	2550
5	0.025	16.5	2060	3000	6400	575	2800	4085

Note: Both schedules at 32 in. wide.

TABLE II

SELECTED MOTORS AND GEARS

Stand No.	Motor		Gear ratio	Roll rpm	Fpm
	Hp	Rpm			
1	1500	70/210	1:1	70/210	400/1200
2	3000	134/335	1:1	134/335	750/1875
3	3000	156/312	*1:1.525	238/476	1340/2680
4	3000	178/323	*1:2	356/645	2000/4000
5	4000	245/445	*1:2	490/880	2750/5000

*Step-up gears.

TABLE III

WR² AND ACCELERATION

Stand No.	Hp	No. of armatures	Type of drive *	Motor rpm	Gear ratio	WR² at motor shaft x 1000			Per cent amps to accelerate motor	Per cent amps to accelerate, Total
						Motor	External	Total		
1	1500	1	SA	70/210	1/1	110	38.5	148.5	25.0	27.0
2	3000	2	DA	134/335	1/1	89	38.5	127.5	23.0	29.5
3	3000	2	SA-T	156/312	1/1.525	66	96.0	162.0	15.6	32.3
4	3000	2	SA-T	178/323	1/2	59	192.0	251.0	18.7	54.0
5	4000	4	DA-T	245/445	1/2	32	192.0	224.0	15.9	68.5
Reel	600	2	DA	250/1000	1/1	2.7	4.0	6.7	18.2	69.0

* SA = Single armature.
DA = Double armature.
SA-T = Single armature twin.
DA-T = Double armature twin.

under consideration. Note that a single armature direct drive was selected for No. 1 stand, a double armature direct drive for stand No. 2, and a single armature twin drive with a 1.525 to 1 step-up gear for stand No. 3, a single armature twin drive with a 2 to 1 step-up gear for stand No. 4, and a double armature twin drive with a 2 to 1 step-up gear for stand No. 5. Note the relation between motor WR^2 and the mill or external WR^2: for stand No. 1, 110,000 as compared to 38,500 lb ft^2; for stand No. 2, 89,000 as compared to 38,500; for stand No. 3, 66,000 as compared to 96,000; for stand No. 4, 59,000 as compared to 192,000; for stand No. 5, 32,000 as compared to 192,000. It is obvious that more can be done by eliminating external WR^2 than by pouring more money into the electric drives. Now examine the per cent current to accelerate each drive from zero

speed to its top rated speed in ten seconds. Compare that required to accelerate the motor only to that required for both motor and mill; No. 1—25 against 27 per cent; No. 2—23 against 29.5 per cent; No. 3—15.6 against 32.3 per cent; No. 4—18.7 against 54 per cent; No. 5—15.9 against 68.5 per cent.

Even by going to such extremes in the design of these drives, it will be noted we did not attain our ideal of having the same per cent accelerating currents for each drive. However, better operation of the mill will be obtained by a gradually increasing per cent from No. 1 stand on, than by hit and miss design. The layout shown is just about as good as is practical to obtain. This tapering of percentages tends to inherently soften the mill during acceleration when there is greatest tendency to break, and to harden the mill during deceleration when there is less tendency to break. This softening and hardening combination is the best inherent approach to obtaining a good compromise between good gage and a minimum of breakage.

A good compromise in design, economics, and production of good strip, is to allow not more than 60 per cent accelerating current for accelerating the motor and mill from zero to maximum speed in ten seconds with motor field setting corresponding to maximum speed.

So far we have examined only the per cent accelerating current to top speed of all motors. This is a good fundamental approach, but it is more important to have a good balance under actual operating conditions. Probably the most popular schedule is that of rolling 0.095 to 0.010 in. This schedule was shown on the speed cone as being rolled at 4000 fpm. The accelerating currents under these conditions are: stand No. 1—9.2 per cent, stand No. 2—10.4 per cent, stand No. 3—14.4 per cent, stand No. 4—28.6 per cent, stand No. 5—43.5 per cent. This is good tapered balance.

Let us go back and take another look at the speed cone (Figure 2) and examine what its spread means. When a motor speed is obtained by adjusting its field strength, and it is accelerated to various speeds in the same time, the per cent accelerating currents vary as the square of the speed. Thus for a 1.5 to 1 speed range motor, the per cent accelerating current up to top speed is 2.25 times that at base speed, and for a 3 to 1 motor, 9 times that for base speed. Thus the wider the speed range, the higher the WR^2 and per cent accelerating current, as well as, the greater the range in accelerating current, which is not conducive to obtaining the best inherent mill drives.

If the 0.025 schedule had been eliminated and 0.013 in. selected as the heaviest strip to be rolled, the basic speed of 300 rpm could have safely been used instead of 245 rpm, reducing the WR^2 and accelerating current accordingly. It is obvious that it is better to open up the entry end of the speed cone, and close up the delivery end. This will make a better balance between drives. Thus the higher the speed of the mill, the more limited should be the products to be rolled.

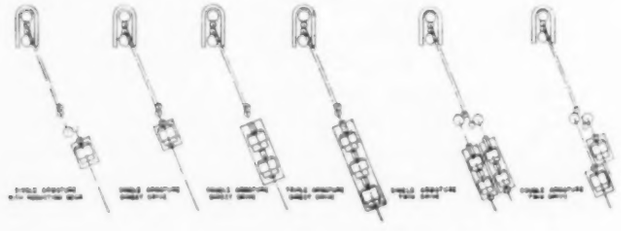
All this led to the development of the so-called single generator scheme, Figure 4, or, in other words, to a separate generator for each motor. If this is a 100 per cent success, and we have every reason to believe it will be, we could use constant speed d-c motors, and all speed adjustment could be obtained by voltage control. This will be a great boon to the building of less expensive and lower WR^2 motors. Likewise, instead of the accelerating current varying as the square of the speed, it varies directly as the speed. Although several of these mills are being built, no one has gone to constant speed motors. Experience will have to demonstrate that the individual generators can be controlled with the necessary accuracy during steady state, as well as transient conditions.

There are four important by-products of this scheme. It limits the interruption of currents to that of one motor and one generator, as well as eliminating the stress to the other motors and generators when a short occurs on one machine. It eliminates the heavy bus and its construction, to withstand short circuit conditions that is necessary for the conventional common generator scheme. And most important, it eliminates the expensive high-current, low-voltage boosters with their attendant relative high maintenance and losses.

It might be well to glance at the fundamental scheme of control which allows the elimination of the booster. The secret to this is the use of a master pilot voltage bus. For the sake of simplicity, one motor and one generator is shown. All other drives are connected similarly to the same pilot bus. The master pilot exciter's voltage is raised or lowered for acceleration or deceleration, respectively. It will be noted that the difference in voltage between the pilot and the main generator is applied to the field of the generator high speed exciter, and forms a basic voltage maintenance control. A voltage proportional to the IR drop of the armature circuit is connected in series with the basic voltage maintenance control field. This voltage fools the master pilot voltage by an amount equal to the desired degree of the IR compensation. In order to adjust for various voltages on the different stands, one end of the voltage maintenance control circuit is actually connected to a potentiometer across the pilot bus, rather than directly as shown.

With the ever increasing size of coils, the ratio of empty reels to full reels is likewise increasing. This means greater and greater speed range by field control for the reel motor, if the usual constant current control scheme is used. We have already seen what this means in the way of inertia and per cent accelerating currents, to a lesser degree, on the mill drives. It is not uncommon to require a 5 to 1 speed range motor. This problem has led to the development of a regulating tensiometer for use with the reel. Since the tension is regulated by a measurement of the tension itself, it can be controlled by either voltage or field control or

Figure 3 — This figure illustrates various drives which can be used on a mill stand.



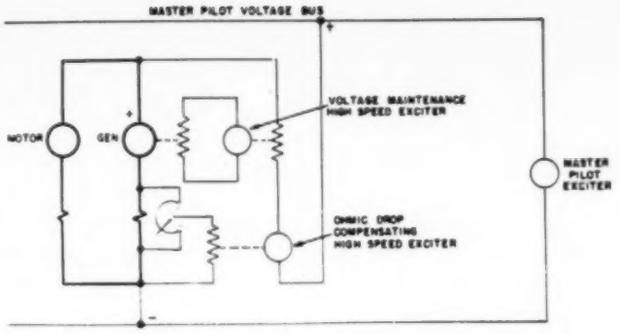


Figure 4 — Diagram shows single generator scheme of control with ohmic drop compensation and voltage maintenance.

by a combination of the two. The latter will usually prove to be the best, and thus for a 5 to 1 buildup we may use a 3 to 1 speed range motor by field control.

Another problem of inertia that will in all probability show up on these ultra-high speed mills is that of accelerating the tensiometer rolls. The friction between the strip and the roll is extremely low, and it may become necessary to use d-c drives on the rolls so that their speed will be proportional to strip speed, in order to prevent slippage.

It may also become necessary to make the coolant and strip lubrication proportional to strip speed. Probably by far the most important problem yet to be solved is that of coolant control, so as to maintain roll shape. This is going to have to be solved by trial and error.

In recent years considerable study has been given to anti-hunt problems, and much progress has been made. If there were no electrical inertia problems, there would be no anti-hunt problems. However, this battle of electrical inertia is being won. If this were not true, the single generator scheme would not have been brought forward at this time.

So far we have discussed only reduction mills, but if you can solve those problems, the temper mills will be easy. Speed range, except for the reels, is not so important in the temper mills, because of the relatively small reductions which are taken. Furthermore, little can be done about gage correction in the temper mill and constant tension to prevent strip breakage is the most important factor.

This paper has necessarily been limited only to a discussion of some of the fundamental problems in strip mill speed-ups. As a final plea, please be sure the drives are laid out as fundamentally correct as possible, even though it means moving the mill to a new location, to get space for the longer and lower inertia drives. Win the battle of inertia and you will have a good mill.

DISCUSSION

PRESENTED BY

R. H. WRIGHT, Steel Mill Engineer, Industrial Engineering Department, Westinghouse Electric Corp., East Pittsburgh, Pa.

F. MOHLER, Patterson-Emerson-Comstock, Inc., Pittsburgh, Pa.

H. W. POOLE, Manager, Steel Mill Division, General Electric Co., Schenectady, N. Y.

R. H. Wright: One spring afternoon about fifteen years ago a group of us were observing the starting of a new type of cold mill. The mill consisted of a tandem train of four-high stands which had been used previously for sheet rolling with rather indifferent regard to tension between stands. The original constant voltage control had been replaced with adjustable voltage control and it was then intended to use the mill to roll tinplate with some control of tension between stands. The maximum delivery speed of the mill was about 450 fpm.

Since this was the first attempt to cold roll tin plate in this plant, the president of the company was present and remained throughout the afternoon. The president was concerned chiefly about the ability of the mill crew to develop the new rolling techniques which he was sure would be required. As the afternoon advanced and good finished coils began to come from the mill, he became convinced that the mill and crew could be made to perform as expected.

In the years that have followed a succession of new tinplate mills have been installed in this plant, each one designed for a higher delivery speed. None of them have given any more difficulty in starting than the first installation for 450 fpm. Having made the first step it has been relatively easy to acquire the knowledge and the courage to make the next advance. True, it has been necessary to discard a number of cherished ideas along the way which had been elevated to the position of basic principles.

At first practically standard electrical equipment was used. Later, mill and motor inertias began to receive attention and by special design a balance of accceleration torques was achieved which helped to reduce the acceleration time. Then, as speed and power increased, ways were found to reduce the acceleration time further, even with the inertia unbalance which is inherent in a high speed mill with twin-motor drives on the finishing end. In the beginning it was satisfactory to control reel tension and compensate for coil build-up with a single regulator operating in the field of the reel motor. Now, with coil build-up of three or four to one, it is necessary to separate these two functions and use two regulators; one to compensate for build-up and one to regulate tension. Other distinct changes in practice have contributed to the success of the latest high speed mills.

The manner in which our ideas have been revised is illustrated by the present practice in controlling the field of a reversing motor. Observation of the instruments will show that at times the current in the shunt field is less than zero. This contradicts an old theory that there should always be at least some current in the shunt field of a direct current motor. However, such drastic action is necessary to overcome the delay in field response which is due to the effect of eddy currents

in the frame of the motor. Although the operation of the control may be unconventional, it does give more rapid acceleration. It takes a certain amount of courage to do these things but they must be done if the demands of modern industry are to be met.

F. Mohler: I would like to make one comment in connection with blooming mills. The highest producing blooming mill in the world is a steam driven mill. It has an accelerating rate of 100 rpm per second. We always thought it did not make too much difference whether it was a second, or a second and a half to accelerate, but that the time taken for manipulation of screw downs, tables, and so forth predominated. However, no time is lost in that mill, and the actual rate of acceleration plays a large part in the production of that mill.

That problem was attacked with quite a bit of misgiving, but final calculations showed by going to laminated frames, and so forth, a rate of 100 rpm per second and better could be obtained.

H. W. Poole: Mr. Mohler mentioned the individual generator scheme for tandem cold strip mills. We have made tests in the factory on such circuits as were shown, with master pilot generators, high speed exciters, etc., and these tests have made us even more confident that we are on the right track in applying the individual generator scheme.

As you can well appreciate, during acceleration the voltages of the five mill stand generators and the reel generator must not only build up rapidly and simultaneously, but must also reach a predetermined value at the same instant without harmful overshooting or oscillation. The speeds of the motors will tend to follow the generator voltages very closely and only a very carefully designed control system can be expected to give satisfactory results.

The question of inertia was also brought up in Mr. Mohler's paper. I would like to emphasize, from the standpoint of the electrical manufacturer, the importance of the combined inertia of the mill motor and the mechanical parts. We are doing our best to keep the motor inertias to a minimum, and we solicit the full cooperation of the mill builders in also reducing the inertia of the mechanical parts wherever feasible. In many instances, the inertias of the rolls, spindles, couplings, and gears or pinions of the last few stands of modern cold strip mills are very large when compared to the motors which drive them.

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METALLURGICAL CONTROL OF COIL ANNEALING IN RADIANT CONVECTOR FURNACES

. . . . more rapid heat equalization in the charge by convection and edge heating leads to greater uniformity in physical properties, and in production and flexibility of operation . . . .

By GEORGE B. ESPEY
Metallurgist
Lee Wilson Engineering Co., Inc.
Cleveland, Ohio

▲ THE trend of modern strip mill design is toward higher rolling speeds. In retaining a reasonably low percentage of non-productive handling time with such installations, coiling diameters have been increased until 60 in. diameter coils are now common and coils up to 72 in. are being wound regularly.

Older methods of coil annealing limited the processing advantages of the larger coils because they cannot be annealed to the desired property uniformity within any economical time. However, the application of high speed convection has overcome these disadvantages and removed the limitation of a maximum coil diameter, for the annealing process.

The purpose of this paper is to report the advantages of the high speed convection furnaces over the older type of furnaces and to discuss their relative performance.

EQUIPMENT

The new high convection radiant convector type furnace installations (1) (2)* differ from low convection furnace installations in five major respects:

1. Small impeller type fans have been replaced by larger, more efficient centrifugal turbine type fans, which circulate the protective atmosphere at much higher velocities, Figure 1.

2. The previous somewhat standard types of bases have been replaced with a circular base plate supported by a ring of "diffuser" blades, the latter serving a purpose similar to that of the ring of stationary blades in a turbine. This specially designed "diffuser base" takes the gases from the fan and delivers them into a narrow annular channel between the cylindrical inner cover and its sleeve liner.

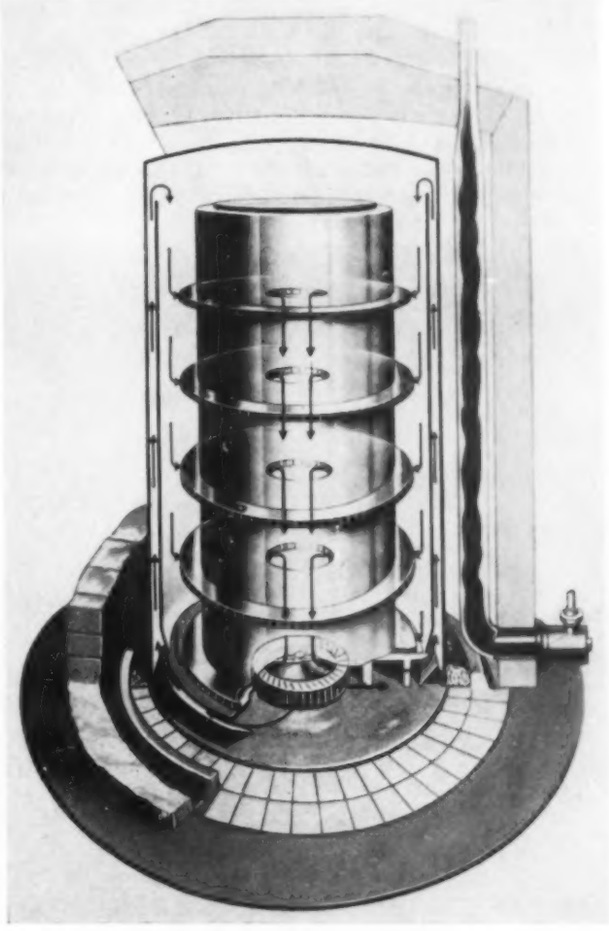
3. The "sleeve liner" has been added to the inner cover to simultaneously maintain the gases under high velocity, direct them along the hot inner cover, and increase the heating surface area, Figure 1. The deliberate wiping principle used for heat transfer is highly important in establishing the extent to which heating rates can be boosted by the addition of convection. This wiping takes on particular significance when it is noted the rate of heat transfer to gases by radiation is practically nil.

4. After being heated, the gases travel into the "convector plates" between the coils, Figures 1 and 2. These convector plates pick up heat from the gases and then transfer it to the coils. The cooled gases return to the fan for recirculation.

The above four changes make each stack of coils and its inner cover an integrated heat exchanger in itself.

5. A fifth difference in radiant convector installations is in the heating capacity of the portable furnaces which are placed over the exchanger stacks. The combustion capacity of each tube assembly for these fur-

Figure 1 — Phantom view of a single stack unit of the radiant convector furnace.



* Numbers in parenthesis refer to bibliography at the end of the paper.

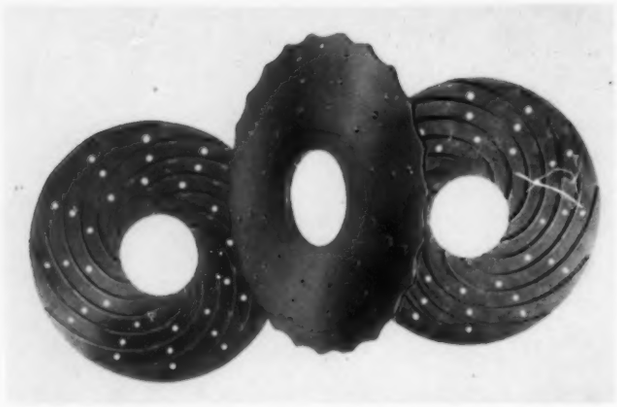


Figure 2 — The two halves go together to make up the final assembly of the convector plate shown in the center of the photo.

naces has been increased to compensate for the doubled to tripled rate of heat absorption of each stack.

As will be seen later, the effects of these combined differences in design are large.

DESCRIPTION OF TEST CHARGES

The relative temperature uniformity and quality control achievable in low and high convection furnaces can best be illustrated by a comparison of some details of results from test charges annealed in representative examples of these furnaces. Pertinent information regarding three such charges of similar dimensioned 15,000-lb coils is given below.

1. Test charge I (tinplate) refers to a charge of 53-in. diameter, 28-in. wide, 15,000-lb coils of 0.010-in. thick strip, heated to a minimum steel temperature of 1100 F in a four-stack (three coils per stack) low convection furnace. (Experimental data from this charge are presented in Figures 4, 5 and 10.)

2. Test charge II (tinplate) refers to a charge of coils identical to those used in charge I, except these coils were charged into a two-stack (four coils per stack) radiant convector furnace, Figure 3. (Experimental data from this charge are presented in Figures 6, 7 and 12.)

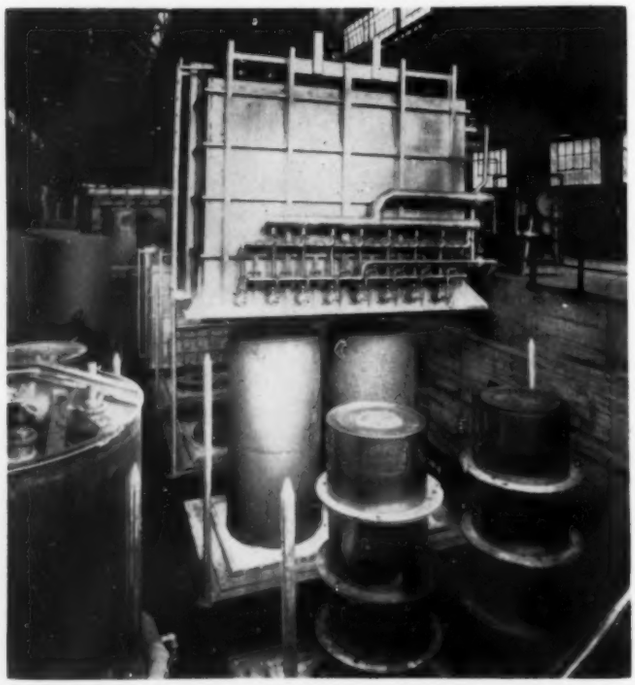
3. Test charge III (deep draw stock) refers to a charge of coils of the same size as those annealed in charges I and II. However, these coils were of thicker 0.035-in., deep draw strip. This charge was heated in the same high convection furnace as charge II but to the much higher minimum steel temperature of 1300 F. (Experimental data from this charge are presented in Figures 8 and 9.)

Thermocouples were imbedded into the coils of these charges to learn the temperature distributions and the different histories of cycle which existed throughout their mass.

The rate of firing and heat input to the above charges was automatically controlled by limiting the tube temperature to 1550 F ± 20 F until the base control thermocouple reached control temperature and assumed control. The base control temperature was set at 1220 F ± 20 F for the tinplate charges (Test charge Nos. I and II) and at 1350 F ± 20 F for the deep draw charge (Test charge No. III). After reaching base control temperature, the firing was regulated to hold this control thermocouple, Figure 4, at constant temperature throughout the remainder of the cycle.

No control was exercised over the temperature of the hottest steel in the charges in either furnace.

Figure 3 — Test charges II and III were made in the two-stack radiant convector installation shown in the foreground. Two of the four stacks of the low convector installation, in which test charge I was made, can be seen in the left central background.



HEATING RATE

In both the low and high convection furnaces, the hottest steel at the outside of the coils was heated at approximately the same rate, Figures 4, 6 and 8.

In the radiant convector furnace, the temperature of the hottest steel followed that of the stationary base control thermocouple closely, Figures 6 and 8.

In the tinplate charge of the low convection furnace, the hottest steel reached as high as 1400 F for an appreciable time and remained above an average of 1300 F for about 20 hours, Figure 4. In contrast, in the tinplate charge in the high convection furnace, the temperature of the hottest steel reached and remained at the much lower temperature of 1220 F for only one-fourth as long or five hours, Figure 6.

Although the outside portions of the charges in both furnaces had similar temperatures during the early part of their cycles and the average final holding temperature of this hottest steel averaged about 100 F higher in the low than in the high convection furnace, it took almost 2½ times longer for the coldest center steel in the low convection furnace to reach 1100 F (40 hours versus 17 hours). Compare Figures 4 and 6. It follows then, that the considerable increase in the rate of internal heating of charges in the radiant convector furnace must be independent of the operation of the furnaces and result solely from the added convection and edge heating.

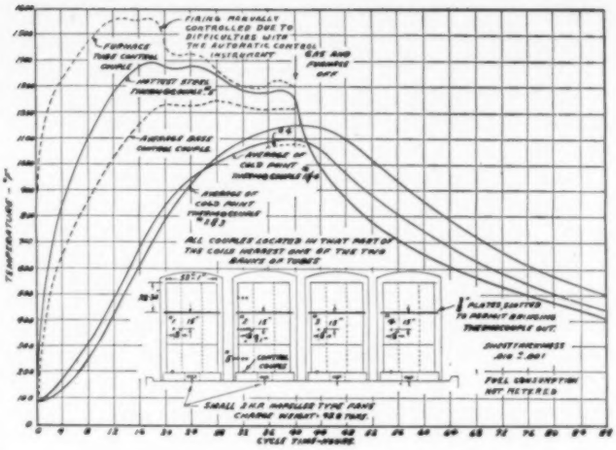


Figure 4 — Time-temperature curves for the control thermocouples and the hottest and coldest steel, during the annealing of a charge of 15,000-lb coils of tinplate in a typical low convection furnace. This charge was annealed at a rate of 0.6 ton per stack per furnace hour. (Test charge I.)

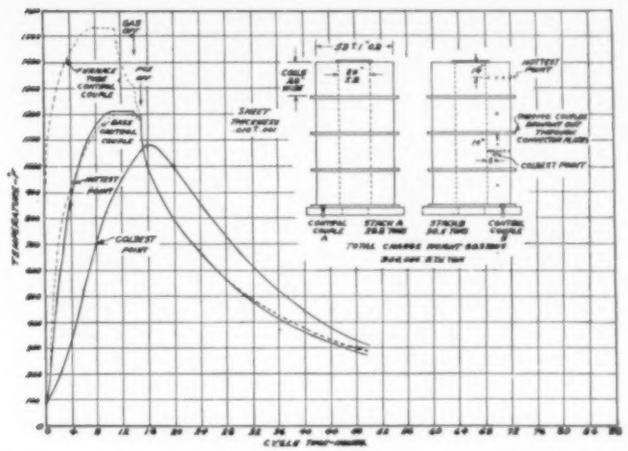


Figure 6 — Time-temperature curves for the control thermocouples and the hottest and coldest steel, during the annealing of a charge of 15,000-lb coils of tinplate in a typical radiant convector furnace. This charge was annealed at a rate of 2.0 tons per stack per furnace hour. (Test charge II.)

It is through this combination of convection and edge heating that a major portion of the heat is allowed to enter and leave the coils from their edges and, thereby, to simultaneously reduce the radial and axial temperature gradients and speed up the overall heating and cooling cycles.

HEAT FLOW ANALYSES

A rough analysis has been made of the relative amounts of radial and edge heating in the low and high convection furnaces. This analysis indicates that the amount of heat input from the edges is approximately proportional to the area of the edges being supplied with equivalent heating. However, perhaps more clearly explanatory of the increased practical significance of increased edge heating is the fact that in the radiant convector furnace considerably over three times as much heat is transferred into (and from) the coils through their edges than from their cylindrical outside surfaces. Details of the supporting analysis are as follows:

The resistance to heat flow within coils is known to be many times greater in the axial than in the radial direction. Theoretical calculations have indicated the relative ease of heat flow to be between 18 and 45.5 to 1 [1, 3, 4] and other evaluations from tests on single coils have indicated similar practical values to be somewhere between 3 and 8 [1, 3], depending upon the tightness of coiling and the thickness of the sheet under consideration.

Although the above values do not have sufficient quantitative agreement to warrant detailed calculations of the actual heat inputs from the cylindrical surfaces and the edges of the coils, some rough evaluations of the relative radial to axial heat inputs strongly indi-

Figure 5 — History of the radial temperature distribution within one of the coldest coils of a tinplate charge in a low convection furnace. (Second coil up in test charge I.)

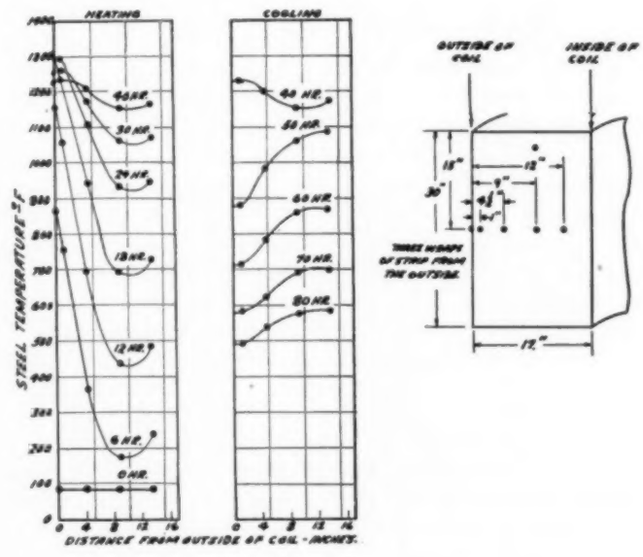
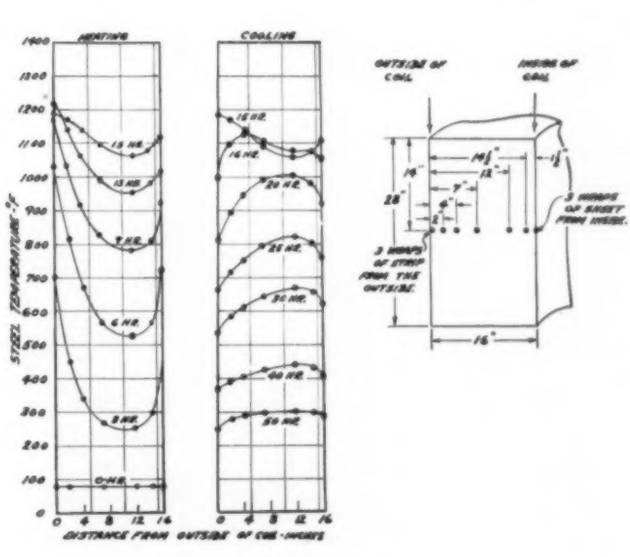


Figure 7 — History of the radial temperature distribution within the coldest coil of a tinplate charge in a radiant convector furnace. (Second coil up in test charge II.)



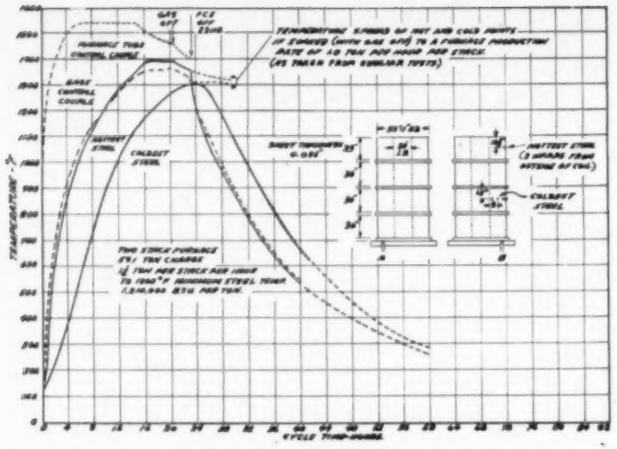
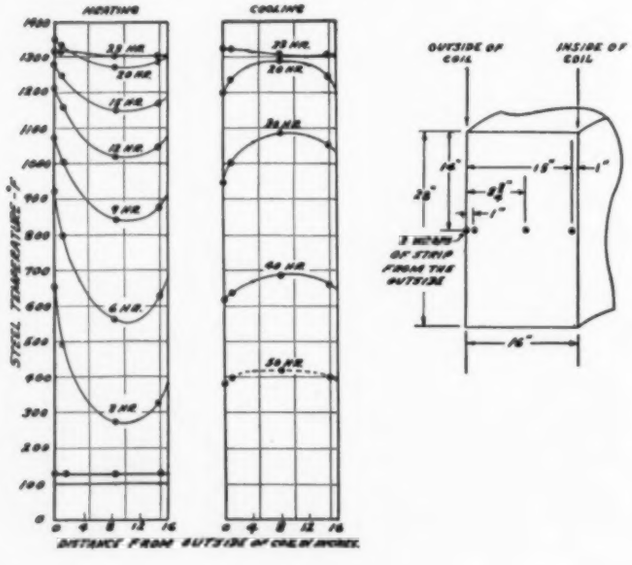


Figure 8 — Time-temperature curves for the control thermocouples and the hottest and coldest steel, during the annealing of a charge of 15,000-lb coils of deep draw stock in a typical radiant convector furnace. This charge was annealed at a rate of 1.25 tons per stack per furnace hour. (Test charge III.)

cate the radial portion of the heat input constitutes only a small fraction of the total heat input in the radiant convector furnace.

Specifically, since the outside wraps of the coils were heated at approximately the same rate in both the high and low convection furnaces, it is to be assumed any difference in the rate of heat absorption of the charge (during this period) is due to increased edge heating. Comparison of the findings from Charge I and II, Figures 5 and 7, shows the average radial temperature gradient and, therefore, the average rate of radial heat transfer, to have been roughly two-thirds as great in the radiant convector furnace as in the low convection furnace. Since the total length of the heating cycle in the radiant convector furnace was, in addition, reduced to about 40 per cent of what it was in the low convection furnace, it follows that the total radial heat input was roughly one-fourth $(0.66 \times 0.40 = 0.26)$ as great

Figure 9 — History of the radial temperature distribution within the coldest coil of a deep draw charge in the radiant convector furnace. (Second coil up in test charge III.)



in the high convection furnace as in the low convection furnace.

This places the increase in axial heat input at about three times the total radial input, if the same ratio of axial to radial heating is considered to exist throughout the cycle.

Disregarding fine points of temperature distribution, and any conduction from the outside edges of the convector plates, the above mentioned three-fold increase in edge heating plus that which would occur through the edges at the bottom and top of the stack (were there no internal edge heating) indicates the axial heat input in radiant convector furnaces to be something over three and probably in the neighborhood of 4 to 6 times the radial heat input.

TEMPERATURE UNIFORMITY

For a comparison of the radial temperature distributions in the two charges, compare Figures 7 and 9

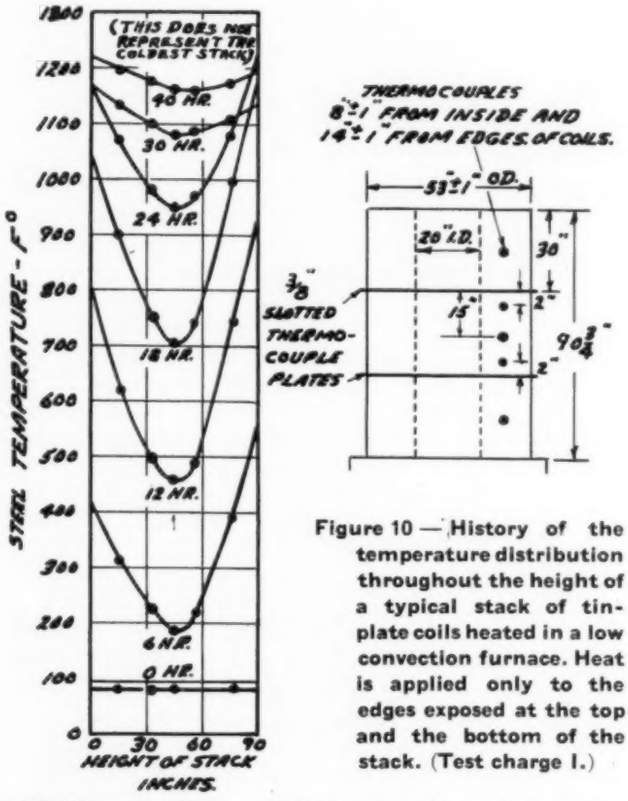


Figure 10 — History of the temperature distribution throughout the height of a typical stack of tinplate coils heated in a low convection furnace. Heat is applied only to the edges exposed at the top and the bottom of the stack. (Test charge I.)

with Figure 5. For a similar comparison of the axial temperature distribution of the same single coils, compare Figures 10 and 11.

It can be seen that by supplying heat directly to the edges of all coils, rather than just to those exposed at the top and bottom of the stacks, the much cooler and vertically elongated core of metal, extending throughout most of the height of the stacks in low convection furnaces, Figure 10, is eliminated and replaced with a more uniform temperature distribution having a scalloped pattern, Figure 11. This pattern derives its form from the similar widthwise temperature distributions of a number of individual coils, Figure 12.

The combined "spill" of the hot gases onto the top of the stack and the considerable "top" radiation from a long flame combine, during the early part of the cycle,

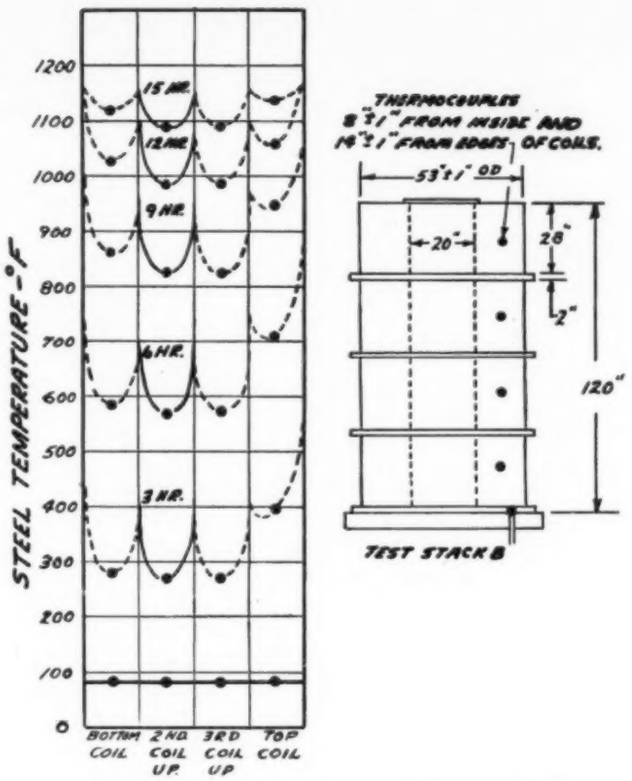


Figure 11 — History of the temperature distribution throughout the height of a typical stack of tinplate coils heated in the radiant convector furnace. (Test charge II, coil size same as in test charge I.)

to heat the top coils of the (cold) stack faster than the lower coils. However, the temperature throughout the height of the stack becomes quite uniform, as the length of the flame is cut back and the charge approaches temperatures where the physical changes of annealing begin to take place, Figure 11.

One of the most important beneficial factors derived from edge heating has been a considerable increase in the rate at which the overall temperature spread between the hottest and coldest steel is reduced. This tendency toward a rapid achievement of temperature uniformity appears to be quite effective in bringing deep draw stock into soak. For such material, it is generally necessary to bring the coldest point in the charge to within 25 to 100 F of the maximum temperature to which any of the steel in the charge is allowed to be taken, at any time during the cycle. The dotted lines in Figure 8 (derived from the results of tests other than those specifically discussed) give a general idea as to the heat equalization achievable when using holding times longer than that employed for Test charge III.

PROPERTY UNIFORMITY

The above discussed factors leading to a higher degree of temperature uniformity give a correspondingly higher degree of property uniformity.

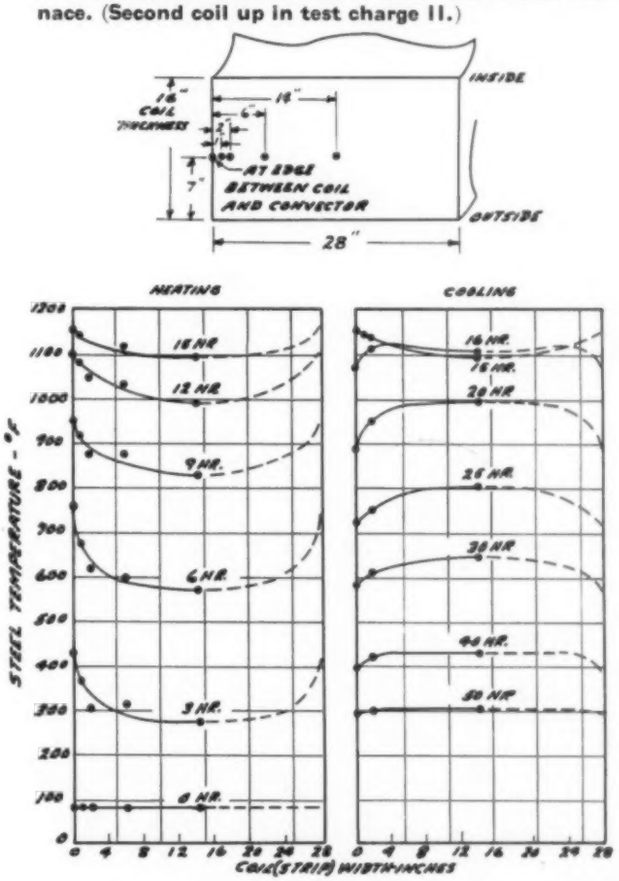
To indicate the amount of property variations attributable to differences in temperature histories, test specimens of sheet of the same composition were wrapped into the tinplate coils going into the radiant convector furnace. Test charge II. These specimens were located at positions identical with those of the imbedded exploratory thermocouples, Figure 6.

The "as-annealed" properties of the specimens, annealed at different points throughout the thickness of the second coil up from the bottom of the test stack, Figure 7, are shown as points in Figure 13. These properties are in close agreement with the dotted lines incorporated into this figure and which represent the properties predictable from extensive laboratory investigations on this same sheet [5, 6]. The test sheet was cold reduced 88 per cent to a thickness of 0.0098 in. and had a percentage composition of 0.09 C, 0.45 Mn, 0.007 P, 0.026 S, 0.003 Si, 0.098 Cu, 0.02 Mn, but a trace of Cr and the remainder Fe.

These dotted lines were obtained by translating the observed effective annealing time-temperature relations into the corresponding properties found in the laboratory investigation, Figure 14.

The "effective" temperatures, used as an ordinate in the top plot of Figure 13, may be defined as those temperatures at which the metal was held for the arbitrarily chosen time interval of three hours. The corresponding property values (i.e. the dotted lines in the plots below this top one) were rather accurately determined from the shape of the time-temperature curves, obtained from the imbedded thermocouples which accompanied the specimens and the use of a rule-of-thumb that each 20 F increase in annealing temperature is roughly equivalent to doubling the time of annealing, or vice versa. For verification of this rule-

Figure 12 — History of the temperature distribution throughout the width (from edge to edge) of a single coil of tinplate annealed in a radiant convector furnace. (Second coil up in test charge II.)



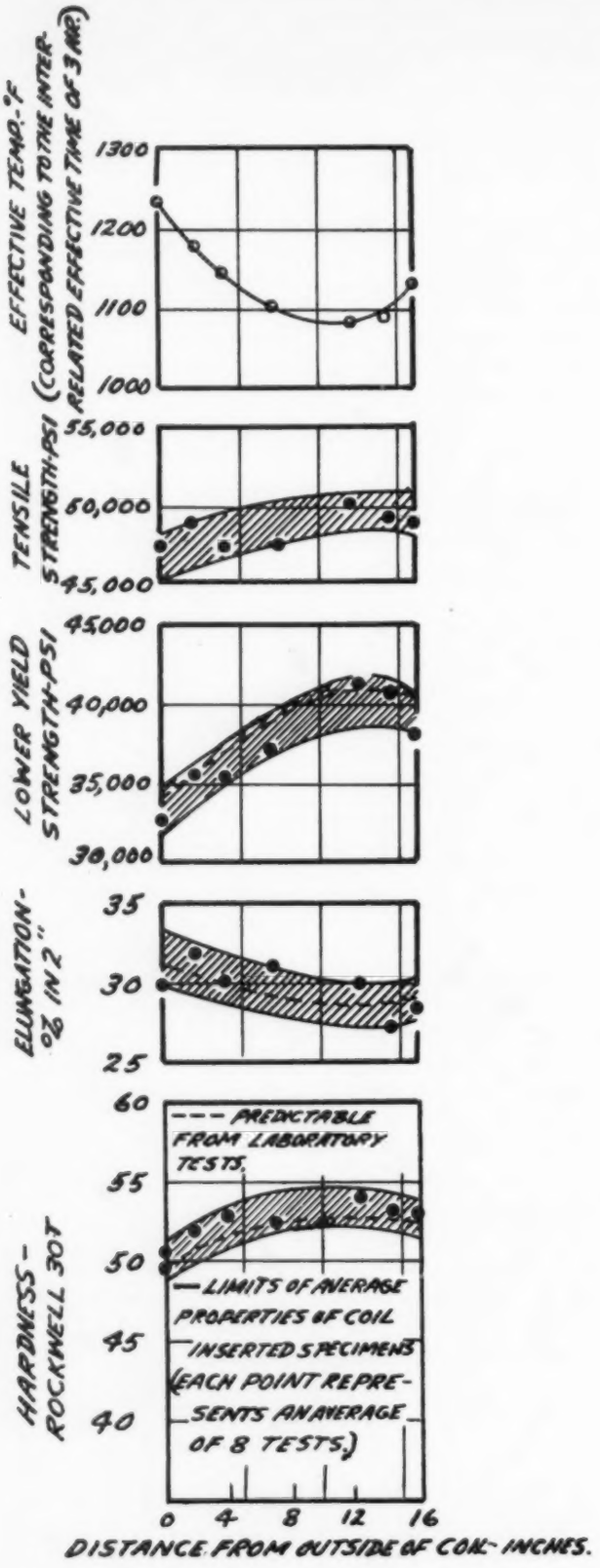


Figure 13 — Property variation in identical sheet samples inserted at different locations throughout the coldest coil in a charge of tinplate annealed at a rate of 2.0 tons per furnace-hour per stack. (Second coil up in test charge II.)

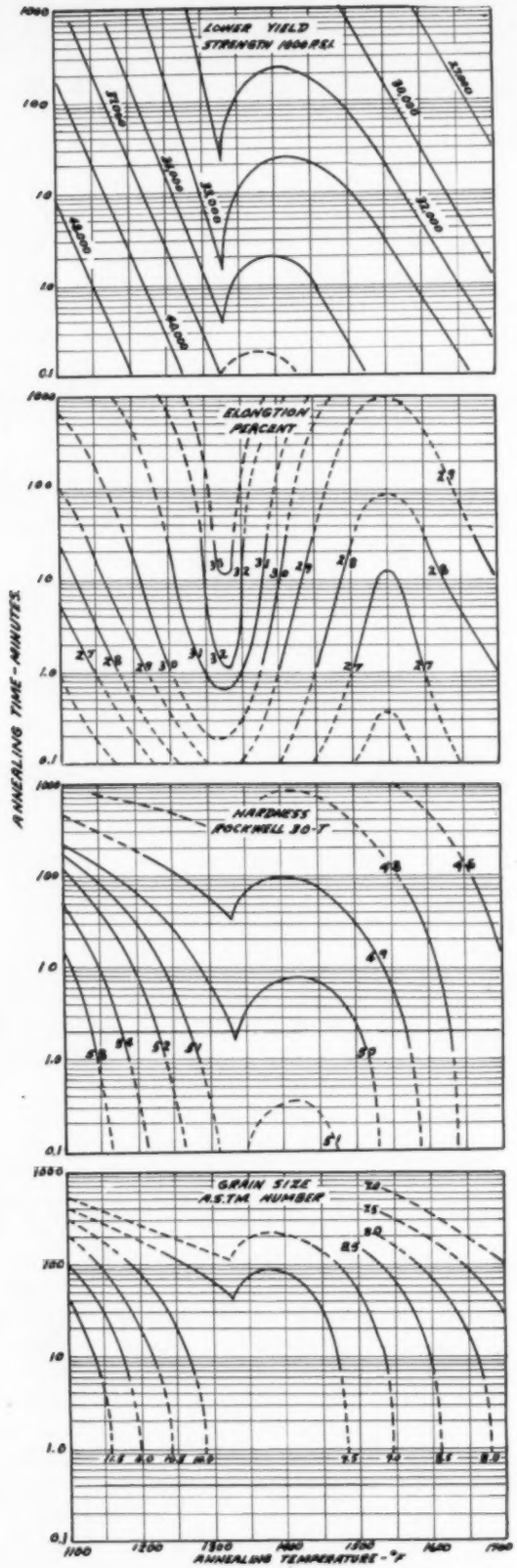


Figure 14 — The effect of various combinations of temperature and time on some properties of annealed steel sheet — 88 per cent cold rolled, 0.009 in. thick, rimmed steel, furnace cooled from annealing temperature.

of-thumb (which, incidentally, is close to that for general chemical activity), study Figure 14.

Sheet specimens were not inserted into the test coils going into the low convection furnace, Test charge I. Nevertheless, property predictions, comparable to those made for the Test charge II, in the radiant con-

vector furnace, likewise, can be made for this charge. First, the time-temperature curves obtained at the coldest points in the two furnaces are of similar shape; compare Figures 4 and 6. It follows that similar properties can be expected for the sheet annealed at the colder central regions of these charges.

In contrast, the time-temperature histories for the outer portions of the charges differed considerably. At the hottest point in the low convection furnace, the steel was held at an average temperature of about 1300 F for 28 hours (Test charge I), Figure 4. While achieving the same final "cold-point" temperature, the hottest steel in the high convection furnace was held at the considerably lower average temperature of 1200 F for between 6 and 7 hours, Figure 6. The corresponding properties, as determined and estimated from Figure 14, are listed in Table I.

TABLE I

PROPERTY DIFFERENCES INDICATED TO EXIST BETWEEN THE TINPLATE TEST CHARGES I AND II ANNEALED AT THE MAXIMUM POSSIBLE RATES OF PRODUCTION IN HIGH AND LOW CONVECTION FURNACES

Properties	Coldest steel. Both furnaces. Properties predicted. (Checked in the high convection furnace)	Hottest steel. High convection furnace. Properties predicted and checked in furnace.	Hottest steel. Low convection furnace. Properties predicted and checked in laboratory furnace.	Difference in the amount of property spreads in steel annealed in the two example furnaces.
Yield strength, psi	41,000	34,500	31,500	3,000
Elongation, per cent in 2 in.	28.5	31	34	3
Rockwell hardness, 30-T	53	49.5	46.5	3
Grain size, ASTM No.	11	9	7	2

It can be seen from Table I that the property differences, stemming from differences in furnace performance and the interrelated time-temperature histories, alone, can be expected to be much smaller in the radiant convector furnace than in the low convection furnace.

PROPERTY UNIFORMITY VERSUS PRODUCTION

The property variations obtained in these specific example furnaces are highly a matter of the degree to which the individual furnaces are pushed for production and of the characteristics of the material being annealed. Figure 16 has been prepared, by estimation (from the previously discussed temperature distribution data and Figure 15), with the view in mind of diagrammatically indicating the differences in the before-temper-rolled Rockwell 30-T hardness, which can be expected in charges annealed at different rates of production in the two example furnaces. The influence (probable) of an average run-of-the-mill variation in chemical composition is also incorporated into this estimate.

The impression which is gained from Figure 16, regarding the comparative degree of hardness scatter at different relative rates of production, is probably not far from that which exists between most typical low convection furnaces and radiant convector furnaces. Although the coils were stacked only three-fourths as high in the example low convection furnaces as in the example high convection furnace, it is to be considered that any increase in the stack height in low convection furnaces can be expected to increase considerably the temperature non-uniformity experienced, if the same time-temperature cycle is maintained at the outside surface of the stacks.

The above indicated differences in the before-temper-rolled properties, characteristic to the two types of furnaces, are of but limited value regarding their ability to predict the property variations to be expected in the final temper-rolled product. However, a number of plant-conducted investigations have shown a superiority for the product from the radiant convector furnace regarding (1) both the amount of reduction and the ease of control required in temper rolling, and (2) the consistency of performance of the final temper rolled product, in subsequent fabrication.

PRODUCTION

The example test charges show that furnace production rates up to and over 2.0 and 1.25 tons per stack per furnace hour can be achieved on tinplate and regular deep draw stock, respectively. See Figures 6, 8 and 15.

However, these rates are not representative of those averaged in general plant production for this size of furnace since in actual production, loading is not always optimum, second, the coldest steel in tinplate charges must usually be taken to temperatures usually between 1125 and 1200 F to obtain consistently satisfactory anneals, particularly for the intermediate tempers of tinplate, and third, longer holding times than shown for Test charge III are required for "extra" deep drawing stock.

Over a considerable period of time, average production rates for tinplate and regular deep draw stock can be expected to consistently approximate three-fourths of the production obtained in the individual test charges, or about 1.5 and 0.9 tons per stack per furnace hour, in four coil high furnaces designed for 54-in. diameter coils, and 30-in. wide. This average rate of production will, of course, be higher or lower, depending upon the size and uniformity of coils charged.

In cooling, the increase in cooling rate brought about by the application of high convection is roughly proportional (i.e. percentage-wise equivalent) to that experienced in heating, down to about 400 F. However, the influence of the heat originating from the dissipation of energy put into the fans becomes appreciable

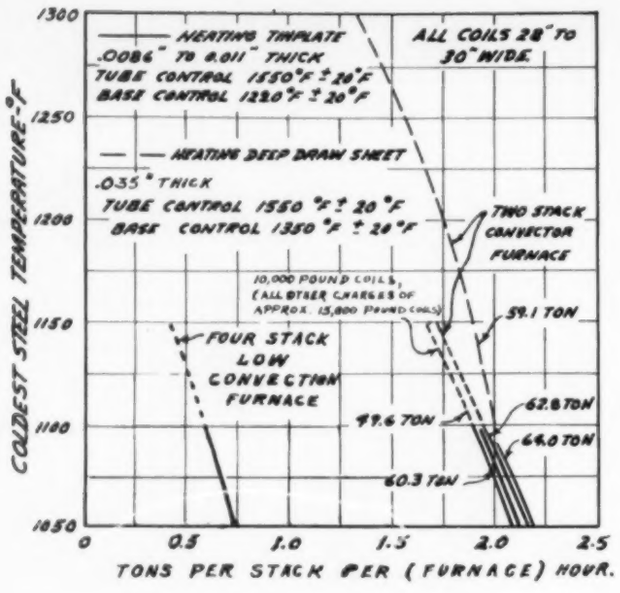


Figure 15 — Relation of furnace production rates to the coldest point (steel) temperature, for charges of two sizes of coils and two thicknesses of sheet.

when and if the charge is taken below approximately 400 F. At temperatures in the neighborhood of 250 to 200 F, this heat input may become sufficiently great to fully offset the increase in heat transfer gained from convection. This factor holds some importance in figuring the base production rates in the annealing of special types of sheet which must be cooled to 300 F or 250 F, to maintain a very bright surface in the as-annealed condition. However, the more uniform temperature within coils cooled under convection can be expected to allow a slightly higher unloading temperature, without danger of the edges and the outside wraps of the coils becoming discolored due to prolonged heat migration from within the coils.

In addition to being rather highly dependent upon the temperature at which the charges are unloaded, the base production rates are also dependent upon the heat absorbing characteristics of the surrounding surfaces and the air circulating past the outside of the cooling stacks. The base production rates for all types of sheet may be considered, under severe generalization, as being roughly in the neighborhood of 40 per cent of the furnace production rates. Under such generalization, 2½ bases per furnace represent the average usage ratio of bases to furnaces for installations having numerous interchangeable furnaces and bases. In single furnace installations, three bases are usually installed with each furnace.

CONTROL AND LOADING

In any furnace, steady operation at consistently high rates of production (with good economy) requires a thorough understanding of the principles behind cycle control. In the coil annealing convector furnaces, major factors influencing the production rates are: 1. the temperature settings of the tube and base controls; 2. the minimum temperature to which the coldest steel in the charge is taken; and 3. the uniformity of the size of the coils loaded into the furnace.

The tube control temperatures are determined from the location of the thermocouple and the interrelated considerations of the best possible combination of average production, fuel consumption, and life of inner covers, tubes and furnace linings. For the radiant convector furnace, a tube control temperature of about 1550 F is recommended.

The base control temperatures are selected mainly from considerations of production versus first the characteristics of the steel being annealed second, the temper desired, and third the degree of property uniformity desired in the charge. The stationary base control thermocouple exercises sufficiently dependable control over the temperature of the charge that no additional hot-point control thermocouples need be used.

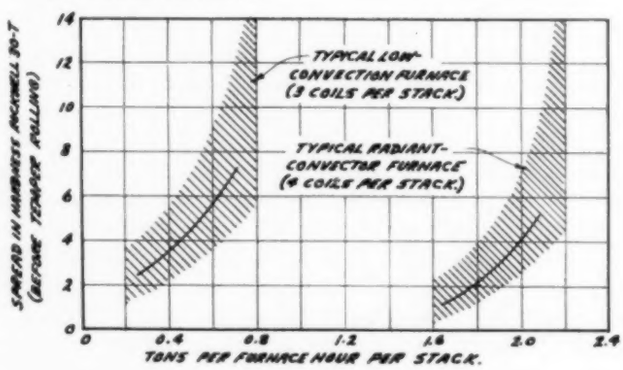
The minimum temperatures to which the coldest steel is taken is particularly significant in the annealing of tinplate. For tinplate, the aim is more to bring the coldest steel to a certain minimum temperature (and softness) than to take the outside of the coils to a "ceiling" soaking temperature and rely upon time for additional softening (and property equalization), as is the case for most deep draw materials.

To obtain the best possible balance of production, quality and economy, it is necessary to take into account the rate and amount of temperature increase occurring at the center of the coils after the firing has been cut back or completed. Depending upon how soon the furnace is lifted from the charge after the gas has been turned off, this temperature increase may be up to 70 F, at the center of the coils, Figure 17.

If any extra furnace time is permanently or temporarily available, it should be added evenly to the cycles of the charges being annealed, either by allowing the furnace to remain on the charge for a time after the gas is shut off, or by decreasing the base control temperature slightly and allowing a longer firing period.

Regarding optimum loading, a few comparative tests on charges of 10,000 and 15,000-lb coils showed no ap-

Figure 16 — This estimate shows the relative amounts of hardness variations to be expected at different rates of production in the example low convection and high convection furnaces.



preciable effect on these size variations upon the production as long as the coils which are charged are of uniform diameter, Figure 13. However, based upon cold point temperature studies, it has been found that the mixing of large and small coils does affect the production noticeably. Even though larger coils heat much faster when charged with a number of smaller coils, the increase in the speed at which the larger-than-average coils are heated is not sufficient to offset fully the decrease in cycle time required to maintain highest possible rates of production. Therefore, although the large amount of edge heating obtained in the radiant convector installations minimizes the effect of variations in coil diameter, the cycles must, nevertheless, be lengthened somewhat when the coil sizes vary greatly in a single charge.

GENERAL

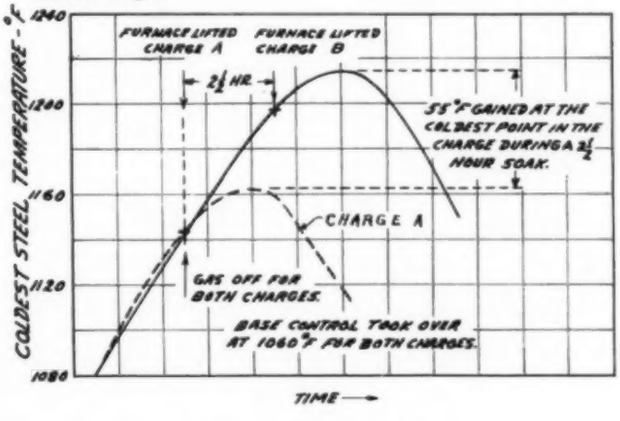
Although differences in sheet thickness have a considerable influence upon the radial conductivity [1, 3, 4] and the rate of radial temperature equalization, compare Figures 7 and 9, they do not appear to have an appreciable effect on the overall heating and cooling cycles in the radiant convector furnace, indicated in Figure 15. This agrees with the previously discussed observations that most of the heat input is from the coil edges and, therefore, is practically independent of differences in the number of sheets (air films) per radial inch of coil thickness.

The large decrease in localized overheating and long holding times has decreased the sticking tendency to such an extent that upper limits of stack heights have not as yet been encountered in high convection furnaces with edge heating. Since large diameter coils can be stacked higher than smaller coils, some high convection furnaces, designed for large coils, have been built for piling heights up to and over 12 ft.

It has been suggested that removal of the sleeve liner of the inner cover constitutes an appreciable reduction in the initial cost of inner covers. Experiments directed to determining the relative rates of production with and without the sleeve liner showed the heating and cooling rates to be decreased by about 15 per cent when this inside portion of the heat exchanger was removed. Although no tests have been made, both the life of the inner cover and the fuel efficiency are, also, probably detrimentally affected by the removal of this part, directing the cooled air stream along the wall of the hot inner corner.

When investment cost, floor space, fuel consumption, power, maintenance, etc., are considered as a whole, high convection installations can be shown to give appreciable economic advantages as well as quality advantages over older style low convection furnaces for the larger coils.

Figure 17 — Superimposed plots of the time-temperature curves of two tinplate charges. These show the effect of a soaking period, after the gas is turned off on the amount of temperature gain at the coldest point in the charge.



MMARY

The influence of combined differences in design between low convection and high convection coil annealing furnaces are large.

Whereas it is almost a certainty that most of the heat in low convection furnaces is transferred to the charge by radiation, it is more than equally certain that the major burden of the heat transfer to the charge in the radiant convector furnace is shouldered by convection. This is strongly supported by the observation of a doubling or tripling in the heating, cooling and production rates which is achieved when edge heating, through convection, is effectively applied to the annealing of coiled strip.

Taking all things into consideration, the combined application of high speed convection and edge heating has simultaneously made possible 1. An increase in the diameter of the coils which can be annealed efficiently, 2. A shortening of the length of batch annealing cycles, by 50 to 65 per cent, 3. An improvement in the control over the property uniformity and property level of the annealed product, and 4. An increase in the general flexibility of operation.

The first factor, the increase in the size of coils which can be annealed, is playing an immediate part in aiding the present trend toward higher speed strip mills. In combination, the latter three factors make it easier for the joint efforts of the metallurgist, production superintendent and management to meet the demands for higher quality, faster production and lower costs in highly competitive markets.

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C. F. & I. ROD MILL

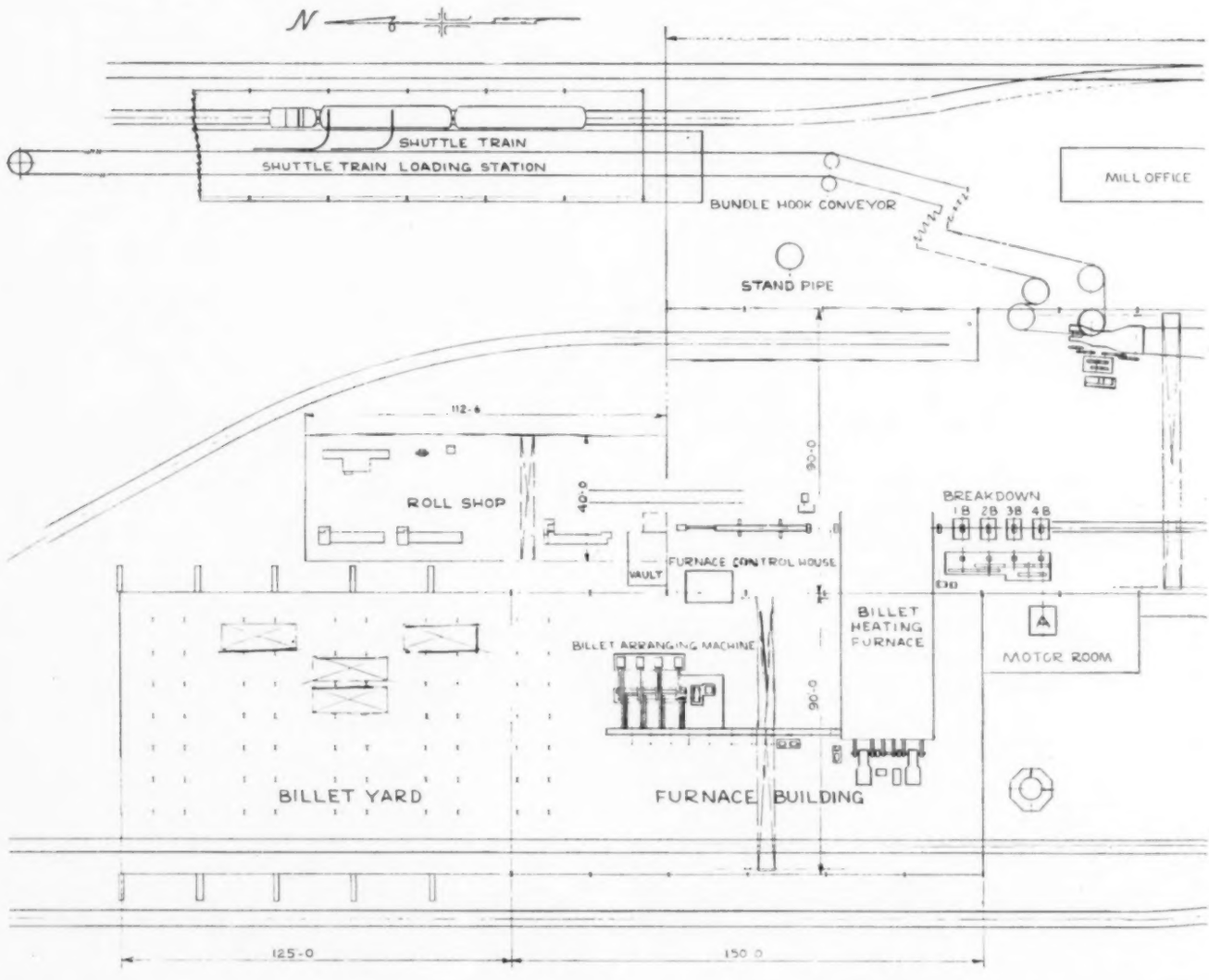
▲ THE new rod mill recently put into operation at the Minnequa works of Colorado Fuel and Iron Corp. in Pueblo, Colo., provides a rolling capacity for coiled rod of more than 200,000 tons per year. Another step in the company's overall program of improvement and modernization, this mill represents an increase of approximately 50 per cent over the previous rod capacity afforded by its predecessor, an old Garrett mill installed in 1903.

The new mill, which cost $5,000,000 and is a complete, independent operating unit, will produce 700-lb bundles, instead of the 165-lb bundles provided by the old mill. Hence, in addition to the improved operating economy of the new mill itself, further gains will be effected in the wire mill, where 14 new continuous drawing machines were recently installed, together with new galvanizing equipment and new high speed netting and welded fabric machines.

Billets, approximately 4⅜ in. square and 22 ft long, for the new mill will be produced in an existing rail mill in the plant, and will be delivered to the rod mill in special billet cars, which are unloaded by an overhead magnet crane in the billet yard or furnace building. The combined billet yard and furnace building is approximately 90 ft wide by 250 ft long, half of which is open and half under roof. The unloaded billets may be placed in storage racks with a capacity for about 8000 tons, or directly upon the rod mill furnace charging equipment, the first unit of which is a novel billet arranging machine. Billet lifts of about nine tons, up to a total of approximately 27 tons, may be deposited at one time on this table, which shuffles the billets in a single layer sideways on to the furnace charging table. This machine operates without manual labor, and is under the control of the operator at the furnace charging station.

The continuous heating furnace, which is rated at 60 tons per hr, is of side-charge, side-discharge design, with a level hearth 69 ft 8½ in. long x 26 ft wide. It is built for top-firing, with coke oven gas in two-zone arrangement. The suspended roof forms a knuckle between the soaking and heating zones, and another toward the end of the heating zone.

Under the action of a pusher mechanism, billets enter the preheating zone through the side wall at the back of the furnace, and are moved over the hearth skids by the action of a pusher mechanism at the back of the



SPEEDS PRODUCTION

furnace. Hearth skids are entirely of the dry type, and consist of rolled steel through the first 40 ft of hearth and of silicon carbide refractory through the next 11½ ft. In the 15 ft 8 in. soaking zone, the hearth is built up of plastic chrome ore, rammed in place and sintered at 2600 F.

The furnace is top-fired with coke oven gas in two-zone arrangement. Pressure of the coke oven gas is controlled at ¾ psi by an automatic regulator, and the temperature of the coke oven gas is also automatically controlled to avoid gum deposits in furnace burners and control devices. A tubular steam heater is used. Automatic temperature control acts to increase or decrease gas flow as may be required, while a counterbalancing of differential pressures across orifices in the gas and air lines acts to proportion air flow in accordance with fuel gas flow. Furnace pressure is also automatically controlled. Safety controls are provided to shut off gas flow in the event of failure of air or gas flow, electrical power, or compressed air used by the gas pressure controller.

At the front of the furnace, another side pusher moves the heated billets out of the furnace into a continuous break-down roll train located close to the furnace. This train, which is unusual in conventional rod mill layouts, is necessary because of the size of billets available to supply the rod mill. It consists of four 18-in. stands, all driven through gearing by a single 2000-hp, 6600-volt, a-c motor. In the four passes of this train, the 4⅜ in. billets are reduced to about 2½ in. squares.

TABLE I

	Length, ft	Width, ft	Cranes	
			No.	Capacity, tons
Main mill building	475	90	1	15/5
Main motor room	250	40	1	25
Breakdown mill motor room	50	25		
Furnace building	150	90		
Roll shop	112	40	1	5
Guide shop and control leanto	150	25		
Shops leanto	50	25		
Shuttle car loading dock	200	35		
Boiler house	35	25		
Office building	67	17		
Comfort station	58	25		
Open billet yard	125	90	1	15

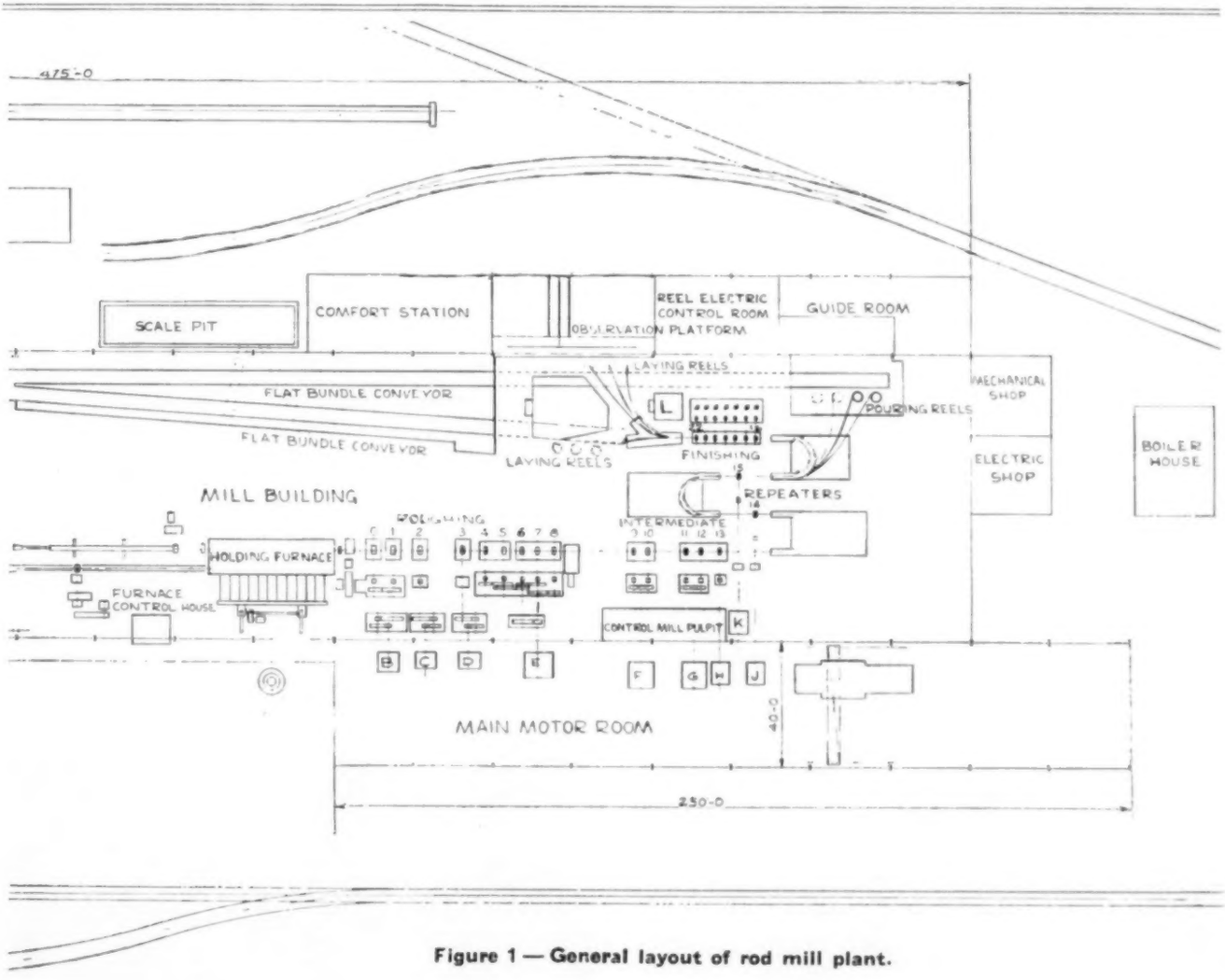


Figure 1 — General layout of rod mill plant.

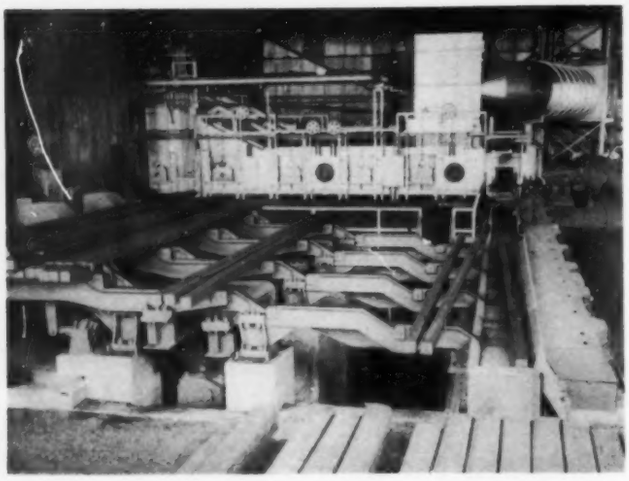


Figure 2 — Crane lifts of billets placed on this unit are shuffled down into a single layer and moved onto the furnace charging table.

This billet is then divided into two pieces, each about 34 ft in length, by a shear located in the mill table which leads from the breakdown train to a holding furnace.

The holding furnace is also a side-charge, side-discharge unit, with a hearth 37 ft wide x 6 ft long, composed of plastic chrome ore. The walls are steel cased, and roof is of suspended construction. Automatic controls and safety devices are provided, similar to those on the billet heating furnace. This furnace, which is also fired with coke oven gas, serves as a reservoir of heated billets for the rod mill proper, while restoring and maintaining temperature of the billets for subsequent further rolling.

The rod mill proper is of more or less conventional modern design. The continuous roughing train consists of nine stands. Stands No. 0, 1, 2 and 3 are 16 in. units, driven through gearing, and as indicated on the accompanying mill layout, by three motors. The remainder of the roughing train (stands No. 4-8 inclusive) is driven through gearing by a single motor.

Following the roughing train is a crop shear, which automatically cuts off the desired length from the leading end of the bar.

Next in line are five 13-in. intermediate stands driven as shown in the layout by three motors.

Leaving the continuous intermediate train, the rod loops back through a repeater to stand No. 14, and then again loops back through stand No. 15. Each of these stands is driven by an individual motor.

Product over $\frac{3}{8}$ in. in diameter (and up to $1\frac{1}{4}$ in. diameter) leaves the mill through stand No. 15 at speeds up to 1600 fpm, and passes to either of two pouring reels. These sizes are at present rolled single strand, but provisions are installed for future double strand rolling. Smaller sizes are produced by again looping the rod through a repeater out of stand No. 15 and back through a finishing train consisting of seven $10\frac{1}{2}$-in. stands and all driven through gearing by a single motor.

Product ranging from No. 5 gage (0.027 in. diameter) up to and including $\frac{3}{8}$ in. diameter leaves the rod mill through stand No. 22 at speeds up to 5000 fpm, and passes to any of six laying reels. Product in this size range may be rolled three strands at a time.

These reels, as well as the two pouring reels previously mentioned deliver the coils to two flat conveyors. These conveyors carry the coils a distance of about 200 ft in approximately 12 minutes to a point where the coils are picked up by a hook conveyor 1400 ft long, having an effective cooling length of about 900 ft, and leading to an unloading station. At this station coils are loaded onto an electrically operated shuttle car system which transports them in carload lots to the wire mill.

Control desks are provided near the pouring and laying reels which give the reel operator full control of the rod after it leaves the mill. Since the pouring and laying reels will not be operated simultaneously, a transfer panel is provided which permits a single auxiliary motor-generator set to serve all reels. The stripper and pushoff drives on the reels are synchronized with the speed of the flat conveyors.

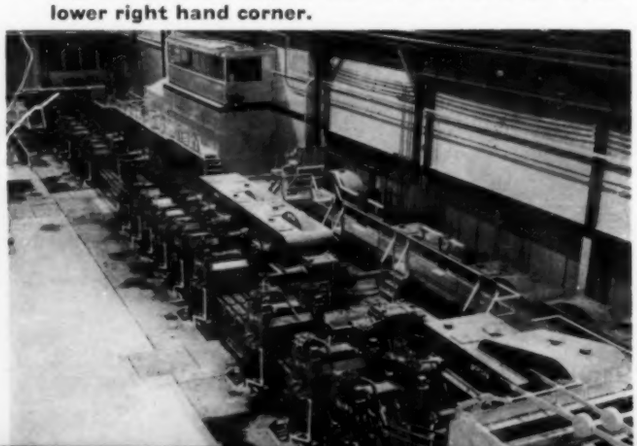
ELECTRICAL EQUIPMENT

All of the ten mill drive motors are of shunt design for 600 volt, d-c and operate under adjustable voltage control. The motor ratings are in the following table.

Power for the ten motors, which represent a total load of 7150 hp, is supplied by a motor-generator set consisting of three 1500-kw, 600-volt generators, driven by a 6300-hp, 6600-volt synchronous motor. The bus to which these generators feed is divided so that one generator feeds the first four drive motors on the mill, an-

Figure 3 — At the exit of the billet heating furnace are four stands of breakdown mill which reduce the $4\frac{3}{8}$ in. square billets to $2\frac{1}{2}$ in. squares.

Figure 4 — The roughing train and intermediate stands of the rod mill proceed in line from the exit of the holding furnace, the top of which is to be seen at the lower right hand corner.



Hp	Rpm
300	225/675
300	300/750
300	300/750
1250	200/500
800	250/625
1000	400/900
400	225/675
400	225/675
400	225/675
2000	500/750

other generator feeds the second four motors, and the third generator feeds the last two motors.

All mill drive motors are controlled by the operator in the main mill pulpit, where a control desk carries facilities for coarse and fine adjustment of generator voltage, and for separate adjustment of the speed of each motor by field control. A master motor-operated rheostat acts to change the voltage for the entire mill from zero to 600 volts, while other rheostats may be varied to adjust the voltage on each individual bus section. Thus, all mill motors may be started by generator field control, while speed changes can be made for the entire mill as a unit. The control system also provides for emergency reversal, dynamic, braking, and protection against overload, undervoltage and overvoltage.

All of the motors are separately excited. Regulation not exceeding 1½ per cent through the entire speed range of all motors is obtained by means of series exciters, while the last two motors (driving No. 15 stand and the finishing train, respectively) are also provided with pilot generators and rotating amplifier control, so their speed may be matched as desired with the drive motors on the pouring or laying reels.

Each of the main mill motors has an overspeed device which will disconnect the motor from the line in case of speeds beyond a preset value, while all motors can be disconnected from their generator bus and subjected to dynamic braking by operation of an emergency stop button.

Temperature relays have been installed on the bearings of all mill motors and the main motor-generator set to guard against overheating or lubrication failure.

The drive motors for stands No. 0-14 inclusive, are located in the main mill motor room, together with the main motor-generator set, control equipment, switchgear, etc. The motor room is kept under a slight positive pressure by a recirculating ventilating system, in which the air passes down through the rotating machinery, through coolers and fans in the basement and back into the motor room. The only opening in the motor-room walls, except for doors which are rubber sealed, is to provide make-up air for the ventilating system. This make-up is cleaned, and heated or cooled as the weather demands.

Figure 6 — Having cooled while being carried by the hook conveyor, the bundles are placed on shuttle cars for transportation to the wire mill.

Power comes to the motor-room at 6600-v, 3-phase, 60-cycles from the plant powerhouse over two three-conductor, 300,000 cir mil cables. This power is handled in the motor room through 12 sections of metal-clad switchgear with circuit breakers rated at 1200-amp capacity and 500,000-kva interrupting capacity.

A 500-kw mercury arc rectifier furnishes 250-volt d-c power for all auxiliary requirements in the rod mill. A 250-v storage battery is provided for switchgear operation, emergency lights and signals, etc.

LUBRICATING SYSTEMS

All main drive gear cases and pinion stands are lubricated by four central lubricating systems, using an extreme pressure additive type oil. One system is located in one oil cellar and the other three in a second cellar.

Figure 5 — This view shows the repeating stands that follow the intermediate train. The finishing train, to the left, is shielded by a steel hood.

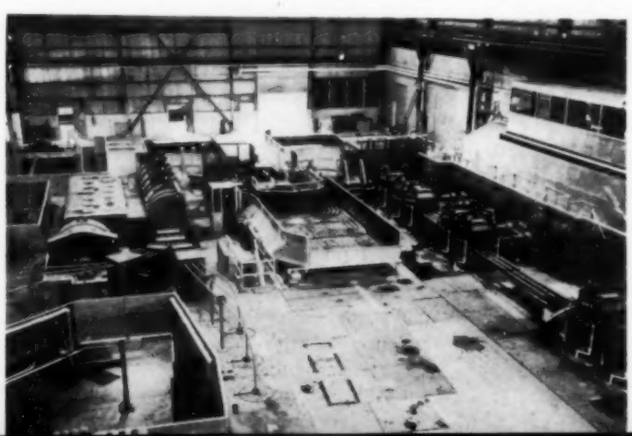
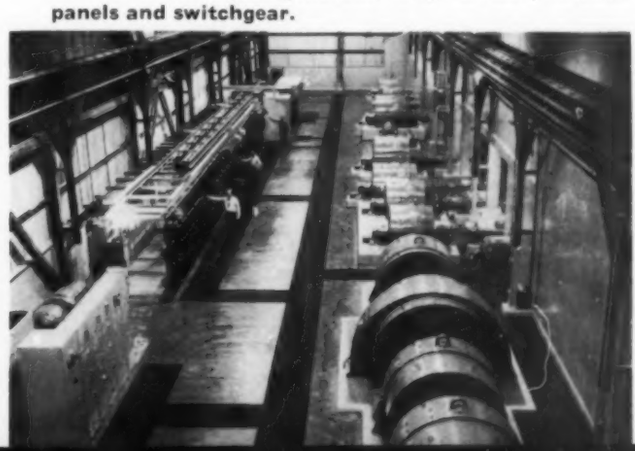


Figure 7 — The main motor room houses the eight motors which drive the first 14 stands of the rod mill, as well as the main motor-generator set, exciters, control panels and switchgear.



The first system, with a capacity of 5000 gal and a circulating rate of 120 gpm, lubricates the gears and bearings of the drive for the four stands of the breakdown mill, the drives for the charging and pushout mechanisms of both the billet heating and holding furnaces, the drive for the bundle conveyors, and the drive for the billet dividing shear.

Another system of 13,000 gal holding capacity and 295 gpm circulating rate lubricates the gears and bearings of the drives and pinions for rod mill stands No. 0-15 inclusive. The third system has a capacity of 4500 gal and a circulating rate of 90 gpm, and serves the gears, mill pinions and bearings of the drive for finishing stands No. 16-22 inclusive. The fourth system, with a capacity of 900 gal and a circulating rate of 20 gpm, lubricates gears and bearings of the six laying reels and two pouring reels.

Each system is equipped with two oil pumps, either of which will circulate the required amount of oil with a maximum discharge pressure of 60 psi. These pumps are automatically controlled by pressure switches, so that in starting the system, both pumps will run until the oil lines are full and the operating pressure reached; then one pump will shut off and not run unless there is a drop in line pressure of 10 psi.

From the pumps, oil flows through an automatically and continuously cleaned revolving disc filter with 0.006 in. spacing. This filter is sized to handle the full oil flow in the system with a maximum pressure drop of three psi.

The discharge of the filter is connected to a small pressure surge tank partially filled with air which serves as a cushion to maintain a steady pressure in the circulating lines. The oil then flows through an oil cooler automatically controlled to maintain an oil temperature of 100 F.

Upon leaving the cooler, oil flows to the main pressure headers and on to the point of demand. After passing over the various lubricated parts, the oil falls to the bottom of the gear case from which it flows to a return header and then back to the main reservoir.

Each system has a thermostatically controlled steam heating coil in the main oil reservoir which is set to maintain the oil temperature at 100 F. Also the larger gear cases are equipped with manually controlled steam heating coils and the supply and return headers are paralleled with steam lines. These are to facilitate circulation of the oil in cold weather.

Each lubrication system is equipped with a system of signal lights and a hawler designed to indicate the operation of the system.

Each oil cellar is equipped with a centrifugal oil purifier to maintain the oil in a clean, moisture-free condition. The supply pump takes oil from the bottom of the main reservoir through a fin-type oil heater to the oil purifier. Each purifier has a recommended capacity of 500 gphr when operating with an oil temperature of 160 to 170 F. The clean oil is collected in a 75-gal tank and pumped back to the main oil reservoir.

BUILDINGS

The rod mill and its auxiliaries are housed in five connected buildings with five leantos, and three separate buildings, all totaling about 87,500 sq ft of floor space under roof. All buildings except the office and comfort station are of steel frame construction, with concrete curtain walls approximately five feet above grade. They are sheathed with corrugated sheet steel, with the exception of the motor room and roll shop walls, where corrugated transite is used. Roofs are of corrugated steel with the exception of the office, comfort station and motor room, which have a wooden deck, and the roll shop, where corrugated transite is applied. Windows are used only in the shops, offices, comfort station and breakdown mill motor room. Instead, steel louvres are used for ventilation in the mill and furnace buildings, and in the shuttle car loading station. The mill and furnace buildings also have open monitors along the roof ridges.

Figure 8 — The new rod mill unit has approximately 87,500 sq ft under roof. In the foreground may be seen the hook conveyor which carries bundles to the shuttle car loading station.

Construction of the entire mill unit, with its auxiliaries, required 68,800 cu yd of excavation and grading, 12,014 cu yd of concrete, 340 tons of reinforcing steel and 1418 tons of structural steel.

The mill is illuminated by a combination of alternately spaced mercury vapor and incandescent lamps, giving an average illumination of 15 foot-candles.

MISCELLANEOUS FACILITIES

Adjoining the north end of the main mill building is the roll shop, which contains two 18-in. roll lathes, one 32-in. automatically controlled form turning lathe, one 20-in. roll neck grinder, and various tool grinders, as well as roll storage racks.

The comfort station provides lockers, showers and washroom facilities for 120 men. Two separate locker rooms are provided, one containing conventional lockers and the other containing elevated hooks for soiled clothing, which can be lowered and raised by chains and pulleys.

Steam requirements of the rod mill are supplied from a completely automatic 160-hp, gas-fired boiler which operates at 150-psi pressure.

Fresh water from the company's reservoir system, at a pressure of 30 psi, is used in the oil coolers of the lubricating systems and the air coolers of the motor room ventilating system. Recirculated water is used on the rolling mill except in emergencies. A 2500-gal stand pipe connected to the mill water system gives protection against water supply failure.

BENEFICIATION OF NORTHERN IRON ORES

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. . . . paper presented before 1949 Regional Technical Meeting of the American Iron and Steel Institute . . . .

▲ BENEFICIATION is the use of technological methods for the improvement of quality and structure of iron ores so as to render them usable in current smelting operations or to improve their usability. In considering the utilization of beneficiation on low-grade iron ores, it is first necessary to examine the need for such treatment. This need is directly related to the reserves of high-grade ore and the possibility of exhaustion of these reserves in the near future. Viewing the iron ore industry as a whole, exact knowledge as to the duration of high-grade reserves and the final technical and economic outcome of exhaustion of these reserves is impossible at the present time. The situation is a complex one involving discovery and location of new ore deposits, the separate activities of large industrial organizations, the national welfare, and finally, the general economic situation in the future. No one knows just what pattern will be finally formed by these factors. But, there is the steady pressure to produce 50,000,000 or more tons of high-grade ore for furnace consumption. Currently about 100,000,000 tons are being produced. If this quantity must be obtained by beneficiation eventually, considerable time is necessary to make adjustments in mining, to determine the most economical flowsheets, to operate pilot plants, and, last but not least, to obtain the necessary finances. Plants must be erected capable of treating 50,000 to 100,000 tons a day with tailing disposal equal to about two-thirds of this amount. Quantity of ore mined must be tripled, as compared with present mining operations on the Mesabi Range. The transition is one of stupendous proportions and preparations must be made far in advance of actual need.

Latest figures reveal that the Mesabi Range yields about 65 per cent of the total ore production in the United States.[1*] The future of high-grade reserves on the Mesabi Range is necessarily a preponderant factor in the steel industry and in the need for beneficiation. Estimates of these reserves differ sharply but, for purposes of planning, the consensus is that 20 years' duration is a safe limit. The Mesabi Range also furnishes vast reserves of low-grade ore. The so-called "taconite" deposit is estimated to contain some 60,000,000,000 tons of crude from which 20,000,000,000 tons of high-grade may be derived.[2] The iron mineral, however, is distributed in the ore in a fine particle size and to liberate this mineral prior to concentration, grinding through 100 mesh at least is required. Concentration of this fine material is by the relatively expensive flotation or reduction-magnetic separation process. Thus the utilization of the Mesabi low-grade ores involves a large increase in operating cost, placing them beyond the range of current ore prices. On the eastern end of the Range, however, there exists a deposit of magnetite ore stated to comprise some 5,000,000,000 tons from which approximately 1,700,000,000 tons of concentrate may eventually be obtained.[3] The cheap magnetic concentration process can be employed on this ore. This, together with a sharp reduction in Minnesota

Figure 1 — The photograph shows a typical Mesabi Range open pit mine. This pit is the Hill Annex at Calumet, Minnesota. The ore in such pits is relatively soft and can be taken out directly with a shovel. In this particular pit, the ore in the pit is handled by truck and moved out of the pit on the conveyor shown at the left.

*Numbers refer to Bibliography at end of article.

taxes on taconite, has apparently brought the magnetic taconite ore within the realm of present economic conditions. At the present time, a proving plant, operated by the Pickands-Mather Co., is in operation at Aurora, Minn., treating 75 tons per hour of magnetic taconite. Grinding is through 100 mesh. Twenty-five tons per hour of concentrate are produced and pelletized by the Minnesota pelletization process.

Thus, by focusing on the Mesabi Range, we have a core of knowledge concerning the future of the iron ore industry. There are, roughly, 20 years to prepare for exhaustion of the high-grade ores. A vast quantity of low-grade ore exists which on beneficiation can produce the tonnage required for the furnaces. On the eastern end of the Range, a portion of this ore is of such nature that it may be treated under present economic conditions. Hence, the transition from high-grade to low-grade is already taking place.

Michigan's low-grade ore is also the taconite type, hematite being the predominant iron mineral. Reserves have recently been estimated to be about 2,000,000,000 tons from which some 725,000,000 tons of concentrate may be derived.[4]

The preceding considerations were devoted to the broad picture of iron ore production, the objective being the maintenance of flow of 50,000,000 or more tons of ore to the furnaces. When, however, we turn to the problems of the individual industrial organizations, a much more urgent situation is revealed. It is not a matter of 20 years, but of one or two years, and methods of beneficiation employed must be clearly economic and immediately applicable. The problem in these cases is not the total exhaustion of reserves, but the maintenance of production schedules. As one deposit is exhausted, another must take its place. The type ore subjected to beneficiation in such cases is known as "intermediate-type" ore. The salient characteristic of such ore is that fine grinding is not required; concentration is performed on relatively coarse particle mixtures, hence, cheap treatments can be employed. In the Minnesota and Alabama ore fields, gravity concentration predominates, whereas in New York and Pennsylvania, magnetic separation methods are employed. Negligible concentration is practiced in Michigan at the present time.

Figure 2 — This washing plant is located about four miles from the pit shown in Figure 1. After the ore has been taken out of the pit by conveyor, it is moved by rail over the trestle to washing plant here shown, where the sand is washed from the ore. The ore is then loaded in cars on the ground level.

In terms of average production of iron ore in the United States from 1942 to 1946, about 15 per cent represents beneficiated intermediate ore from the Lake Superior district, three per cent from the Northeastern district, and one per cent from the Southeastern district.[5] Thus the bulk of the concentrate comes from Minnesota. Reserves of Minnesota crude intermediate-type ore are estimated at 300,000,000 tons of producible concentrate;[3] those of the northeastern district at 500,000,000 tons of crude.[6] In the overall picture of the iron ore industry, the intermediate-type ores are not important due to relatively low reserves available. But they are supplying current needs at current prices and at present are filling the gap between supply and demand.

The raw materials of beneficiation are, in the main, the products of nature occurring at or near the surface of the earth. While there is considerable variation in chemical composition and physical form of these products, yet from the point of view of beneficiation they are treated in accordance with a few simple principles. A low-grade ore is an aggregate of different species or kinds of minerals, the minerals occurring in particle or grain form of varying size. In most cases, these mineral particles are consolidated in a rock which may be original or partly decomposed. In other cases, they may be a simple mixture of free particles of the constituent minerals. Where the particles are consolidated so that there is attachment of particles of different kinds of minerals to one another, severance or liberation is required prior to concentration. This is ordinarily accomplished by crushing or grinding. The size range resulting from this crushing or grinding determines the concentration method as well as the economics of the treatment. For example, at the present time any iron ore requiring crushing and grinding through 325 mesh to effect liberation is questionable as to economic beneficiation under present conditions, regardless of the method of concentration employed.

Concentration is the separation of the particles of one mineral species from the others and this is effected substantially in all methods by means of differential motion. We are dealing with a mixture of particles of different mineral kinds and by imparting motion to one kind different from the others, separation is effected. This is the almost universal method employed in concentration—differential motion of particles of one species of mineral from those of another. This differential motion is usually accomplished by three broad methods: (1) gravity concentration, wherein particles of different specific gravities move differently in a resistant medium such as water or air; (2) magnetic separation, wherein magnetizable mineral particles take different paths in a magnetic field as compared with non-magnetizable particles; and (3) flotation, wherein particles of one mineral kind are reagent coated so that they adhere to air bubbles, and the buoyancy of the bubble-mineral aggregate causes motion to the surface of the liquid whereas the non-adherent particles remain in suspension.

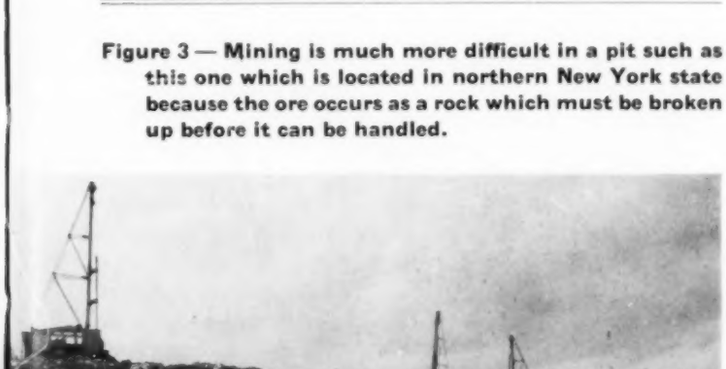
Subsequent to separation, we have agglomeration or

reconsolidation of the usable mineral so as to prepare it for the smelting operation. The blast furnace cannot retain material less than approximately ¼ in. size, and where concentrates are too fine, it is necessary to join the particles into larger aggregates. In the size range of ¼ in. to 100 mesh this is accomplished by sintering, whereby a moistened mixture of coal and ore is burned by means of air being sucked through the heated mass. Consolidation takes place, forming chunks. Where the ore is preponderantly below 100 mesh in size, the porosity of the bed is too low to permit adequate passage of air. A different method is now being tested on a plant scale. This is the so-called Minnesota pelletization method, whereby moistened concentrate containing 50 per cent or more of minus 325 mesh fraction is rolled into balls by means of a rotating cylinder. These balls are then baked in a shaft furnace which causes hardening and resistance to impact and abrasion. The method is rated as cheaper than sintering and production runs are in progress at Aurora, Minn.

Gravity processes are utilized in Minnesota and Alabama and to a small extent in the northeastern district. In such processes, the phenomenon that is utilized is that minerals of higher specific gravity settle faster in water than those of lower specific gravity. Various mechanical devices are employed that fit best the characteristics of the ore to be treated. The most important of these characteristics are (1) magnitude of difference in specific gravity of the minerals, (2) size range present after liberation, and (3) shape of the particles.

In a vacuum, all mineral particles regardless of specific gravity, size or shape, move toward the earth with equal acceleration and, if started at the same instant, with equal velocity. Hence, no separation is possible. When, however, such particles are immersed in a resistant medium such as water, differences in settling velocity are distinct. Mineral particles of higher specific gravity settle faster than those of lower specific gravity. This effect, therefore, must be produced by the medium. In a vacuum, the only force operating is the force of gravity, but in a resistant medium, two new forces are introduced, buoyancy and friction. If this situation is analyzed in detail, it will be found that buoyancy is the force responsible for the difference in settling rates between particles of different specific gravities. Furthermore, this unequal settling takes place without regard to size or shape of particle. It is based solely on difference of specific gravity.

Figure 3 — Mining is much more difficult in a pit such as this one which is located in northern New York state because the ore occurs as a rock which must be broken up before it can be handled.



Friction, on the other hand, is a force that interferes with the effect produced by buoyancy. It acts against the differential derived from this force. Size and shape of particles are intimately linked to the force of friction and it is because of this that gravity concentration is inefficient and complex. As a result of friction, fine particles of high specific gravity settle equally with coarser particles of lower specific gravity and separation cannot be made. This is known as size interference. In one case this effect of friction is helpful. Where the ore impurity consists preponderantly of fine low-specific gravity mineral, such mineral is slowest settling and easily separated. In Minnesota, over 80 per cent of the beneficiation is done by simple water washing of the ore so as to remove the fine silica and produce marketable concentrate.

The force of buoyancy can be magnified by raising the specific gravity of the medium. This can be done by increasing the proportion of ore solids to water or by adding a separate mineral of very high specific gravity to the ore pulp.

We have, then, two situations in gravity concentration: (1) when a mechanical arrangement is so contrived that buoyancy is a predominant factor, then sharpest separations take place and there is negligible size interference; (2) when buoyancy is less predominant, friction causes size interference as well as slowing up of the differential motion as a whole. Separation is much more difficult.

The effect of friction can be overcome by introducing special conditions to enhance buoyancy. In the jigging process where the ratio of solid to liquid is large, one commercial installation treats a size range of 1¼ in. to 150 mesh. In the heavy density method, where fine medium is introduced, the size range is 1¼ in. to 4 mesh. Jigging, however, is expensive and the concentrate is lower grade than by heavy density.

It is in the finer portions of the ore that friction predominates and causes interference. To eliminate this interference, it is necessary to divide the feed into narrow size bands within which fine material of higher specific gravity settles faster than the coarser gangue minerals. The finer the ore, the slower the overall settling rate and the longer the time required to obtain separation. Hence, on finer ores, the capacity of machines decreases and the size and quantity of machines is larger to treat a required tonnage.

In practice, we find that buoyancy is most efficiently applied on a size range of 1¼ to 3/16 in. This is utilized in the so-called heavy-density process which will be described later. Below 3/16 in., friction enters as so important a factor that only imperfect application of buoyancy is possible. Methods devised to treat the minus 3/16 in. range are full of complications. No single machine can treat the full range; most give only a partial answer. Some give a good answer but are difficult to use. For example, we are finding that the shaking table can concentrate ore from 3/16 in. to 20 mesh and from 20 mesh to 150 mesh when treated separately. Yet this machine is of such small capacity and requires so much floor space to treat a high tonnage, that its application is problematical. The hydrosizer makes a partial concentration on minus 10 mesh feed. The Humphreys spirals handle ore from 10 to 20 mesh to 150 mesh. A new machine claims to concentrate from

3/16 in. to 65 mesh. Another is being tested on 65 to 325 mesh. Below 325 mesh no one has or expects an answer by means of gravity concentration.

The trend at the present time on the range is to use spirals even up to 4 mesh. The reason for including the coarse fraction of 20 mesh to 4 mesh is that no satisfactory method has been found applicable to this range. Including it in the spirals feed effects higher iron recovery but with lower grade of product.

The reason for utilizing gravity concentration is that it is cheap. Magnetic separation would be far superior if the iron mineral were magnetite. But with hematite, the only economic method is by gravity processes. Flotation cannot be employed on material coarser than 65 mesh and even on the minus 65 mesh material it is still too expensive.

In Minnesota, there are two types of intermediate ores, one known as wash ore, the other as "jig" ore. In wash ore, the silica particles are much finer in size than the iron mineral particles. Hence, a sizing operation can effect concentration. This is simply and cheaply done by suspending the ore in water in a container, allowing the coarse material to settle, and overflowing the fines. The machines employed are log washers and mechanical classifiers.

Over 80 per cent of Minnesota shipments of beneficiated ore represent wash ore. The remainder is known as "jig" ore, and contains silica particles of the same size range as iron mineral particles. Hence, more elaborate concentration methods are necessary. The name "jig" ore was derived from the machine that originally was employed to treat such ores. The jig is now almost obsolete on the Mesabi Range, having been replaced by the heavy-density process.

The heavy-density process utilizes the phenomenon that when finely ground mineral of high specific gravity is suspended homogeneously in water, a new liquid medium is formed having a higher specific gravity, higher viscosity, and higher resistance to movement of particles. By varying the proportion of suspended particles to the water, the specific gravity can be raised or lowered. When minerals of different specific gravities are introduced into this medium, the lighter can be made to float and the heavier to sink. However, as the introduced minerals are decreased in size, more and more interference with the separation takes place due to the high resistance to motion and an increase in viscosity brought on by the presence of the fine minerals to be separated. As a result, in plant operations the lower size limit is around 4 mesh or 3/16 in. The upper size limit on iron ores is 1½ in. Within this size range, a highly successful separation is obtained, and the use of heavy density is rapidly expanding on the Mesabi Range.

The material suspended in water is ferrosilicon, having a specific gravity close to 7 and ground through 65 to 100 mesh. Sometimes, magnetite is employed in conjunction with ferrosilicon where low specific gravities are desired. Specific gravity of the liquid medium varies from 2.6 to 3.2.

Apparatus employed consists of two units; the separatory unit and the medium purification unit. The separatory unit consists of screens to remove fines, a cone or a mechanical classifier into which prepared ore and medium are introduced, followed by screens to separate the medium from the concentrate and tailing. This medium goes to the purification unit which consists of magnetic separators and dewatering machines. The so-called "densified" medium is then reintroduced into the circuit.

As an example of heavy-density separation, the test results in the accompanying table were obtained on a Minesota ore in our laboratory. It is expected that the same results can be obtained in plant operation.

TABLE I

RESULTS OF HEAVY-DENSITY SEPARATION TESTS ON A MINNESOTA ORE

Specific gravity of medium	Per cent weight of feed	Concentrate, per cent		
		Iron	Silica	Iron recovery
2.70	90.0	58.48	12.02	96.28
2.85	79.5	59.56	10.14	87.01
3.00	69.4	60.72	8.54	77.02

It can be seen from these results that by adjustment of the specific gravity of the medium, concentrates of different grades can be obtained with corresponding changes in recovery.

Magnetic separation is employed preponderantly in the northeastern section of the United States including New York, New Jersey and Pennsylvania. It is based on the phenomenon that the iron mineral magnetite is easily magnetizable; hence, when particles of magnetite are passed through a magnetic field, they take a different path from particles which are non-magnetizable. The explanation of magnetization is that the molecules or atoms of substances are unit magnets. In magnetizable materials, the molecules can rotate easily; hence, when placed in a magnetic field, north and south poles line up in the same direction. The over-all magnetic field is then the sum of the unit magnetic fields. In non-magnetizable substances, the molecules cannot rotate, the unit magnets neutralize one another and the over-all field remains at zero or low magnetic intensity. When a substance is magnetized, the space surrounding it becomes energized or activated, and when brought into contact with a similarly activated space, reactions occur which are reflected in the motions of the material bodies to which these activated spaces are linked. Thus, a magnetized bar of steel can be suspended in mid air with no material support. Below this piece of steel is another bar of steel, also magnetized. The space between them is energized and keeps the upper bar suspended in mid air.

Magnetic separation is the cheapest and most efficient of all beneficiation processes. There is no size interference as in gravity concentration except where the feed is composed predominantly of slimes. Here, there is the lumping of the fines with most of the impurities trapped in the lumps. But most ores do not contain such a predominance of slimes and no serious problem is present. The greatest difficulty with magnetic separation is that the major tonnage of iron ore reserves contains the non-magnetizable hematite rather than magnetizable magnetite. Thus, the process has limited application. Hematite can be reduced by heating and

using reducing agents such as carbon monoxide or hydrogen, but the cost of this method is high at the present time. Efforts are constantly being made to reduce this cost to within economic limits.

In the practice of magnetic separation on a high tonnage basis, it has been found that the magnetic field cannot be adjusted so as to make a sharp distinction between free iron mineral and iron mineral attached to gangue. A particle of quartz with 10 per cent of its weight as attached magnetite will go into the concentrate together with free iron mineral. Thus, segregation of attached mineral particles into a separate middling product, which is common in other processes, does not take place in the magnetic process. However, advantage is taken of this factor to reduce crushing and grinding cost. The ore is crushed to produce free gangue mineral, considerable locked mineral, and some free iron mineral. It is then subjected to magnetic separation which segregates the free gangue mineral only, which is rejected. The reduced quantity of concentrates is then crushed finer and the process repeated. By this means, less and less quantity of material is subjected to crushing and grinding to the point where complete liberation takes place and final grade of concentrate is attained. The standard flowsheet for magnetic separation is stepwise liberation and concentration based on the characteristic behavior of the magnetic field.

On the eastern end of the Mesabi Range, there is a deposit of magnetite ore running about 25 per cent iron, estimated to contain about five billion tons, from which 1.7 billion tons of concentrate may be derived. This deposit originally contained hematite, but an intrusion of igneous rock reduced the hematite tc magnetite and at the same time consolidated the ore into an extremely hard rock. Drilling for mining operations is expensive and for a long time this deposit was uneconomic to treat. Changes produced by the war and a lowering of state taxes has apparently made it possible to exploit the deposit. Pickands-Mather Co. is now operating a 75-ton-per-hour pilot plant producing high-grade pellets as final product for blast furnace use. If successful, full scale plants will be erected.

Machines currently employed for magnetic separation are of the belt type and the drum type. The belt-type machine has an endless belt, the lower branch of which runs through ore pulp flowing through a compartmented box. Above this portion of the belt is an electromagnet with the north and south poles alternating. As the belt passes beneath the magnet and through the pulp, magnetite adheres to the belt until it passes beyond the magnets. It then drops into the concentrate compartment of the box. Alternating north and south magnets cause rotation of the magnetic particles so as to free trapped gangue.

The drum-type machine has rotating cylindrical drums immersed part way in the pulp with stationary magnets inside the drums. The pulp also flows through a box usually containing three compartments, each with its individual drum, the three drums operating in series. Concentrate from the first drum is retreated by the second, and the second concentrate by the third drum. The drum-type machine appears to be superior to the belt type on fine material and is being used on the magnetic-taconite at Aurora, Minn.

Flotation has not yet found application in iron ore concentration due to the fact that it is a relatively expensive process and requires a large investment in plant. However, if taconites are to be beneficiated, flotation will loom as an important method of the future. Hence, it is reviewed here.

In flotation, a suspension in water of ore particles 35 mesh and finer is agitated in a cell through which air bubbles are rising. By adding the proper chemicals to the pulp, mineral particles of one type adhere to the air bubbles and rise to the surface, forming a froth which is skimmed. Thus, one mineral is removed and the other or others remain in the pulp, flowing through a series of cells to the discharge end of the machine.

The adherence of mineral particles to air bubbles is effected by the use of a special type of organic compound having a characteristic chemical composition and physical properties. Molecules of such compounds consist of two primary ingredients. One is a hydrocarbon portion characterized by water repellency and water insolubility as well as chemical inertness. The other is a water-soluble, water-attracted, chemically-active group attached to the hydrocarbon portion. Oleic acid is an example of a common type flotation collector. This compound contains a straight chain hydrocarbon group of 17 carbon atoms and to it is attached a carboxyl group. At an interface between water and air, such molecules become oriented with the hydrocarbon projecting into the air and the carboxyl remaining in the water. When oleic acid is dissolved in water (it is slightly soluble), the surface of the water can be shown to have the properties of an oil rather than of water. The hydrocarbon portions of the oleic acid molecules concentrate in the surface layer and thus cause the change in properties.

When particles of an ore pulp and flotation collector are mixed together in water, the collector reacts selec-

Figure 4 — Separation of non-magnetic ores is a most difficult problem and shown here is an operation in a new pilot plant completed in 1948 at the Benson Mines, New York. The first of three stages of spiral concentration is illustrated where crude ore is carried down the spiral channels by wash water. The waste material is washed to the outer lip while the iron minerals work their way to the inner portion where they are tapped from the inside of the channel.

tively with the mineral particles of one kind and the effect of this reaction is to cause adherence of collector to mineral. Adherence and selectivity are based on chemical phenomena and the whole field of chemistry is available for utilization in devising separations of minerals from one another.

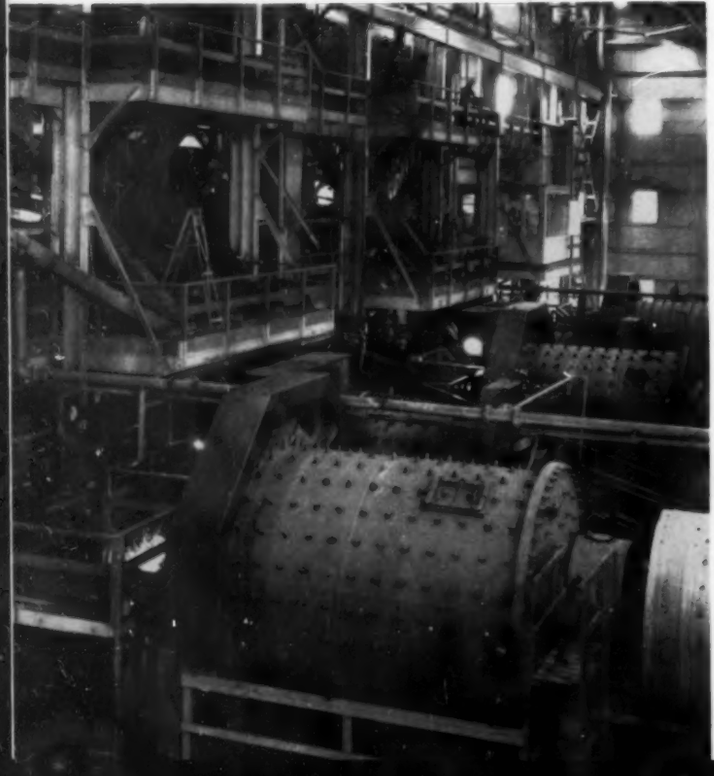
Once a flotation collector has been properly attached to a mineral particle, adherence to air bubbles follows automatically. On contact of bubble and coated mineral particle, the force of water repellency is brought into play and acts to resist separation because separation means re-entry of the hydrocarbon into the water phase.

Frequently a mineral does not react with a collector or if it does, it is desired to suppress this reaction. By the use of auxiliary reagents, it is possible to alter the chemical nature of mineral surfaces so that reactions different from normal are obtained. Thus, iron minerals react with oleic acid-type collectors and normally are floated. By the addition of soluble starch, the iron mineral becomes coated with this material and its reaction with oleic acid prevented. Addition of lime causes alteration of quartz surface so that a reaction takes place with the collector. Quartz now is coated with collector and it adheres to air bubbles. In this way new separations are devised and methods of separation can be developed on any combination of minerals.

Flotation revolutionized the nonferrous metal mining industries because substantially all ores that were liberated at sizes adequate for gravity concentration were depleted years ago. Ores now treated resemble the taconite ores and flotation is the only method applicable. However, on iron ores, the possibility of reducing hematite to magnetite must be considered and it remains to be seen which method will eventually be adopted.

Flotation, when compared with gravity concentration and magnetic separation, is a relatively expensive process. The existence of ore reserves that can be concentrated by these two methods keeps flotation in the background. In the course of time, however, as the high-grade and intermediate ores become more and more difficult to obtain, flotation will emerge as an important method and may become the predominant process.

Figure 5 — At the Benson Mines concentrating plant, the crude ore is first ground to a sand in the barrel-like rod mills.



As indicated in the opening paragraphs, the maintenance of a flow of 50,000,000 or more tons of high-grade ore to the furnaces will involve a stupendous transformation in the iron mining industry when such ore must be obtained by beneficiation. The magnitude of beneficiation operations will increase accordingly. The production of 50,000,000 tons or more a year of high-grade concentrate means the mining and treatment of about half a million tons of crude per 24-hour day. Mining must be performed in hard rock as contrasted with the loose material now being dug. Crushing and grinding must be done so as to reduce boulders four to six ft in size down to 100 mesh or finer. Beneficiation must be followed by pelletization. Large scale plants will be necessitated to gain greatest economy and minimize the inevitable increase in cost.

Plant investment to treat taconite-type ores has been estimated at $10 to $20 per annual ton of concentrate. At 50,000,000 tons annual rate of production, this means ½ to 1,000,000,000 dollars. This money involves no generation of compensating profit, but is an expense to maintain ore production and a charge against future profits of the industry.

The question naturally arises as to how this transformation from high-grade to low-grade ore will take place. How will such a complex and unpredictable situation finally be resolved? The answer is given by the individual exploratory projects now in operation or those which are definitely on the planning board. Mention has been made of the Pickands-Mather proving plant. In addition, the Reserve Mining Co., a subsidiary of Oglebay Norton & Co., has taken initial steps leading to the construction of a magnetic taconite concentration plant at Beaver Bay, Minn. Final output is expected to be 10,000,000 tons a year. Cost of plant is estimated at $100,000,000, equivalent to $10 per annual ton. This is for the simple magnetic separation process. Plant cost will be higher for non-magnetic ore. This same company has started operation of a pelletizing pilot plant at Ashland, Ky., to prove the practicability of agglomerating taconite concentrate. Another company reports that flotation can be successfully applied to a lean specular hematite ore from the Republic formation in Michigan.

It is these pioneering projects that are paving the way toward the final answer. As experience is accumulated and success achieved, the magnitude and scope of operations can be increased.

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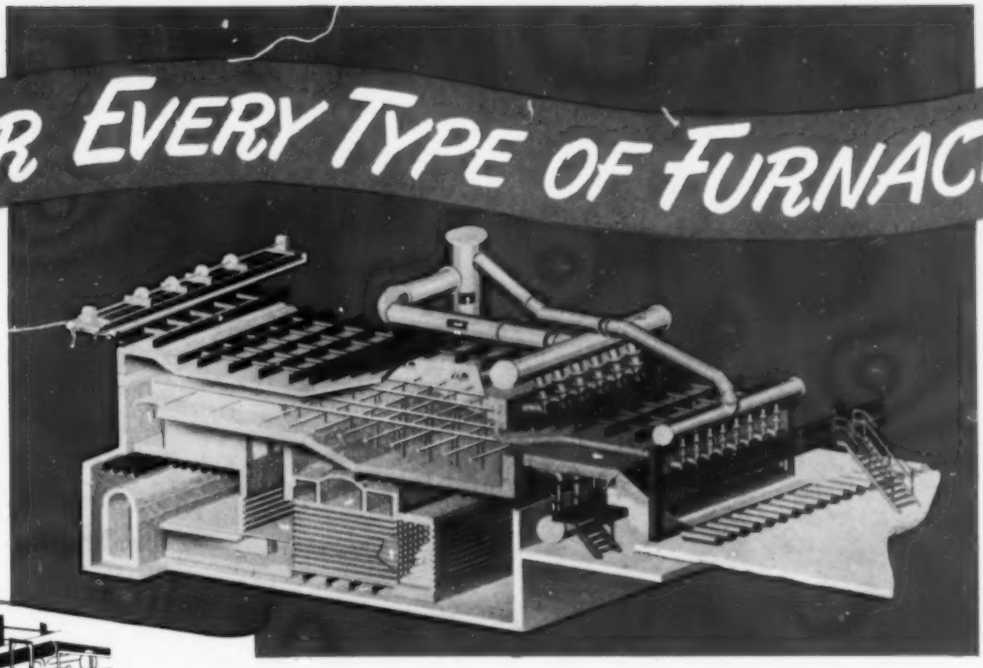
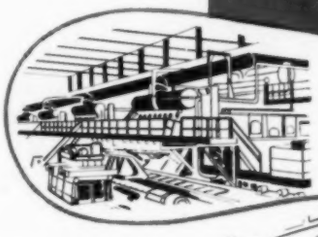
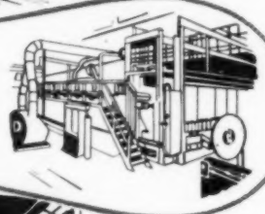
FOR EVERY TYPE OF FURNACE

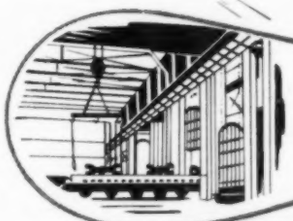




SLAB, BLOOM, BILLET, BAR HEATING FURNACES

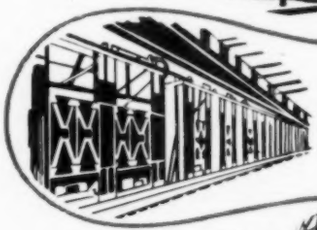


CONTINUOUS PIPE ANNEALING FURNACES

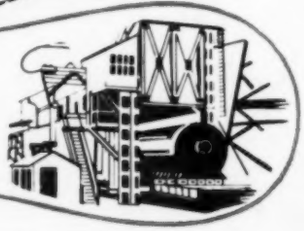


CAR BOTTOM TYPE HEAT TREATING FURNACES

ROTARY HEARTH, BLOOM AND BILLET HEATING FURNACES



BOX ANNEALING FURNACES



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COST CUTTING IN BRITISH STEEL

By R. H. FRY
Industrial Editor
Manchester Guardian

▲ The modernization of the British steel industry has made much progress since the end of the war. Recent visits to some of the steel works where large construction is being carried out show that the £280,000,000 ($784,000,000) expansion program drawn up in 1945 has borne significant fruit. The steady increase in steel production has been making headline news every month for the last two years. In 1935-38, average output of crude steel in Britain was 11¼ million long tons. In 1945, when the development plan was being drawn up by a joint study group of the steel manufacturers, production was just under 12 million long tons. By 1948, it had reached nearly 15 million long tons, and for 1949 it looks as if it will be as much as 15½ million. By 1953-4 normal production capacity is intended to reach 17½ million long tons.

These figures have attracted great political attention. Output could not have risen as it has without a particularly good effort of managements and labor; the workers are still operating the continuous working week without flagging, and the companies have had a difficult job in procuring enough coke, scrap, and other production factors for the growing output. It is also true that the expansion of output could not have been achieved without the new plant and equipment which has been steadily coming into production.

A number of schemes in the total project—which consists of a number of coordinated plans by individual firms—has so far been completed. That is, however, a bad way of describing it. The plan is inevitably in an unbalanced stage: some of the largest items, like the huge integrated iron, steel and sheet-rolling plant at Margam in South Wales, are more than half way towards completion, but will not start up for at least another year. No official estimate is available but about half the work required for completion of the plan has already been done. The plan itself has been changing a little; while the major projects are proceeding as fast as labor, equipment, and construction materials can be obtained, some of the minor schemes have been rendered less urgent by the rise in construction costs. Older but still efficient plants which were scheduled for replacement are being kept going a little longer because with the present relation of construction costs and steel prices, there would be no saving in production costs from the new plants, while the additional output from these facilities, which would be lost during reconstruction, is of vital importance to the British steel-using industries in the next few years.

But cost cutting is an important purpose of the project. Much has already been achieved. New blast furnaces, some of them among the biggest in the world, have been completed at the Clyde iron works in Scotland, in Consett, Durham, and at Margam in South Wales. A new ore preparation and sintering plant, aimed at saving about 15 per cent of coke in iron production and yielding a more uniform quality of pig iron, has just been completed at a cost of $4,000,000 at the Cleveland, Yorkshire, works of Dorman, Long & Co.

Similar ore preparation equipment has been installed at Corby in Northamptonshire, and at Scunthorpe, where steel is produced from local ironstone. In a large number of steelworks, new coke ovens and steel furnaces have been coming into operation, most of the new melting furnaces being fired by oil. A variety of rolling and finishing mills for billets, wire rod, tubes, tinplate, and other products, are under construction. At every steelworks one is told of savings made either in the input of fuel and raw materials, or in time, or in labor. The total effect of British steel costs cannot yet be judged. Too many uncertainties lie ahead. But it is already certain that the industry will be far better equipped to face the competitive struggle that is clearly coming than it has been for thirty years.

Compared with the general level of British industrial prices, steel prices have been kept down considerably. The government's index of wholesale prices shows iron and steel products 85 per cent above the 1938 base, which is the smallest rise of any major group of industrial products. In round figures, coal costs 148 per cent more than in 1938, cotton textiles 285 per cent more, woolen textiles 190 per cent more, chemicals and oils just double. The total index for all wholesale prices is 127 per cent above 1938, so that steel sticks out as having risen less in price than any other major industrial material. It may be, of course, that steel was too dear in 1938, but it certainly would have risen more if the industry had not succeeded in cutting its costs. It cannot expect even the proportionate benefit from all the recent construction and re-equipment until the whole project is more or less complete. At present some plants which are designed to reach fully integrated production by 1952 must be unbalanced. The proper cost saving from new transport facilities, new ore preparation and blast furnace plant, and even new steel furnaces and slabbing mills, cannot be expected if all this mass of new plant has been designed to feed a great new strip rolling mill that is not yet ready for action. Once the whole project is substantially complete, output should jump forward and volume production should slash costs.

WESTINGHOUSE

Looks to the Future

▲ With the twentieth half gone, a group of engineers from the Westinghouse Electric Corp. have taken time out to trace achievements in their various fields and to attempt an estimate of developments to come. From their papers, which appear in full in the Westinghouse Engineer for January 1, 1950, the following forecasts have been summarized:

TURBINES

Discussing turbines, D. W. R. Morgan, vice president in charge of Westinghouse South Philadelphia plant, states that the pattern in the next several years for the large turbine is rather well established. After some pause at the present 1050 F level, the economics of rising fuel and labor costs will bring to being a large 1100 F turbine. Perhaps the next step to 1150 F will soon follow, but this would require better materials than are now at hand.

Machines of larger maximum capacity are clearly in the short-range picture. In the not-too-distant future turbine generators of 150,000 to 200,000 kw are likely to be in demand.

Using known designs, materials, and near-future steam conditions, turbines larger than 150,000 kw would be cross compounded to obtain the advantages for the high steam conditions of 3600-rpm and the ability of the 1800-rpm construction to accommodate the accompanying tremendous exhaust-steam volume.

The reheat principle has reappeared and seems likely to be an adjunct of future high-economy, large-capacity units of further advanced steam conditions.

Turbine standardization has been successful and popular, but the top limit of standards — 60,000 kw — is small for the larger systems. In the light of recent developments, standardization of a 90,000-kw machine is indicated and preliminary consideration might be given to one of 135,000 kw.

Atomic power stands as a potential means of furnishing heat for large production of electric energy by steam-driven turbines, and should be reduced to practicality at the earliest time. However, the development work that lies before it is so prodigious that the only logical conclusion at the moment is that central-station use of atomic energy is some years away.

If research provides suitable materials and if the economic situation becomes such as to justify ultimate thermal efficiency regardless of machine cost, there might come a turbine built for steam conditions of 1200 F and 3206 psi pressure, which is the pressure at which water and steam have the same density. This would give a turbine with about 40 per cent thermal efficiency compared with today's anticipated best of about 37 per cent.

For the 3200-psi turbine to retain the mass-flow relations of the high-pressure stages, the rating should be at least 240,000 kw, possibly more, and even 500,000 kw would be possible. Such a unit for 1200 F, 3200 psi might be a cross-compound machine with multiple-flow low-pressure section and a high-pressure element of the multi-cylinder type, with the first stage in tandem or geared to this 3600-rpm element.

At present the gas turbine stands about where the steam turbine stood at the beginning of the century. Its development, for all its obstacles, should be rapid.

GENERATORS

Generators to go with the turbines of the future are entirely practical, according to C. M. Laffoon, manager of a-c generator engineering. The rapid increase in capacity of individual generating systems and the heavy power inter-change connections between adjacent systems already justify generators of 200,000 to 225,000 kw. These can be met with single-unit, 3600-rpm hydrogen-cooled generators of present-day construction operating at 30-psi gas pressure.

With reasonable improvement in the physical characteristics of alloy forgings, and somewhat better rotor ventilation, and insulating materials, it is anticipated that 3600-rpm, 250,000-kva single-shaft generator units can be built as soon as the need for them arises. On the basis of the same

design condition, single-unit, 1800-rpm generators can now be built for ratings of 350,000 kva and perhaps more.

The greatest possibilities for still larger increases in ratings can be expected from new insulation materials, improved methods of ventilation, and the use of new cooling media.

Many new promising synthetic insulating materials are already available, as yet untried in windings, offer prospect for considerable improvement. Insulations eventually will be almost wholly man-made or synthetic.

The greatest gain will result from the development of far superior methods of using either the present or new cooling media to dissipate the losses with the lowest thermal drops from the seat of the loss to the cooling medium. In the future the primary design problem of a-c generators will be to obtain a much greater output per unit of materials used. It is believed that generator outputs per pound of active material will be increased from 33⅓ to 50 per cent.

SWITCHGEAR

Switchgear to handle greater concentrations of power will be available as needed according to J. B. MacNeill, manager of the switchgear division, who states it seems fair to assume that alternating current generation and transmission will continue to supply the bulk of our power. The problem of circuit interruption can be covered adequately by conventional oil circuit breakers, compressed-air breakers or oil-poor breakers, in the portions of the field for which each is most practical. Studies of interruptions over wide current ranges indicate that proper design will handle the currents on high-voltage circuits without undue distress up to the limits now foreseen for power-system service—even up to 400-500 kva.

High-voltage d-c remains a possibility for future power transmission. Should it come about, the transformation from a-c at the generators to d-c at the line, and back to a-c at the load presents formidable problems for the electrical manufacturer and especially for the switchgear designer.

System engineers, of course, keep power concentrations under fault conditions within the limitations of the available apparatus, however, it is repeatedly found that increased ability to handle faults and to reclose rapidly is an economical method of assuring high-grade service on important transmission systems.

Large power concentrations are practical with modern high-speed switchgear, but it cannot be assumed that present interrupting capacity will be adequate for even the near future, since short-circuit kva figures of 12,000,000 or even 15,000,000 kva have been considered. The American switchgear industry can produce apparatus to handle these concentrations when required.

TRANSFORMERS

In speaking of transformers, F. L. Snyder, manager of transformer divisions, sees in the reasonably near future the maximum commercial operating voltage increasing from its present level of 287,000 volts, possibly to the neighborhood of 400,000. Whether operating voltages higher than 500,000 will ever be required in this country is doubtful, but should such be the case, transformers for such super-voltages are expected to offer no insurmountable problems.

There will be an increase in the maximum kva that can be built into a single unit and shipped completely assembled from the factory. A top level of 145,000 kva has been reached this year, and 200,000 kva can be provided when needed.

It seems certain that the three-phase transformer will be dominant. Large high-voltage power transformers will probably be forced-oil-cooled instead of self-cooled, and this trend will continue until gas-filled units supplant them. The complete factory-built, fully coordinated unitized substation will largely supplant the conventional substation built piece by piece in the field.

The transformer designer would welcome a new core material capable of carrying more flux with lower loss. The possibilities of grain orientation will be pushed to the limit, and there is possibility of a new alloying agent, other than silicon. Cobalt offers possibilities. The most hopeful direction for another major gain in core material appears to be in a rearrangement of the electrons in the outer orbits of the iron atoms.

Also, the designer includes among his dream materials a conductor of lower resistivity than copper. At the present there seems little prospect of this in any known alloy or metal, but the possibility of using low temperature to obtain this result should not be ruled out.

A third much desired improvement would be a solid insulation with dielectric strength much higher than anything now known and with exceptional thermal conductivity and stability.

Perhaps, instead of the solid dielectric, some new synthetic fluid—liquid or gas—will be produced that is a better insulating medium than oil. Such a medium may be used under several atmospheres pressure, thereby obtaining the advantage of greatly increased insulation strength.

Some engineers suggest that the trend in electrical insulation for high-voltage apparatus may lead in the opposite direction—to no liquids or gases and no high pressures, but instead, a high vacuum. If an efficient heat engine could be developed capable of operating on low temperature differences it would be possible to use the heat developed within the transformer to effect its conduction to the atmosphere.

MOTORS AND CONTROL

L. R. Ludwig, manager of the company's motor division at Buffalo, observes that the degree of enclosure of motors has been steadily increasing, and seems to be leading to a single completely enclosed, self-cooled motor that can be used for all jobs now requiring general-purpose fan-cooled motors and for many, if not most, of the other applications demanding special enclosures.

The problem is principally one of ventilation. The recently developed silicones may supply the answer to higher temperature insulations, but some way must be found to maintain a reasonably cool motor frame even though the electrical parts may run at quite elevated temperatures. A possible solution may involve a radical new method of cooling, such as employing latent-heat of vaporization of a liquid.

The principal causes of motor failure continue to be bearings and windings. Recent progress in adapting sealed ball bearings is a long step in reducing maintenance cost. Such motors have been in service for 12 years with no lubrication or change in the bearings. Progress is being made in insulations to reduce winding fail-

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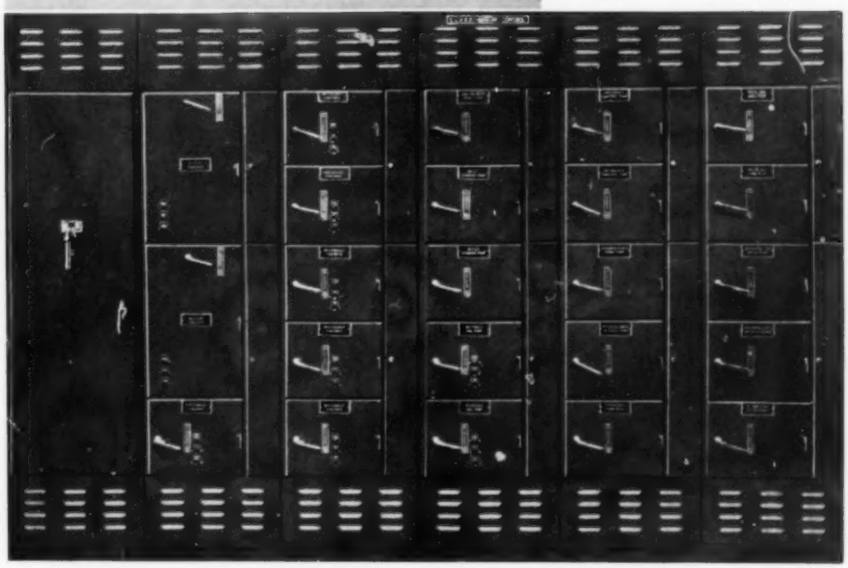

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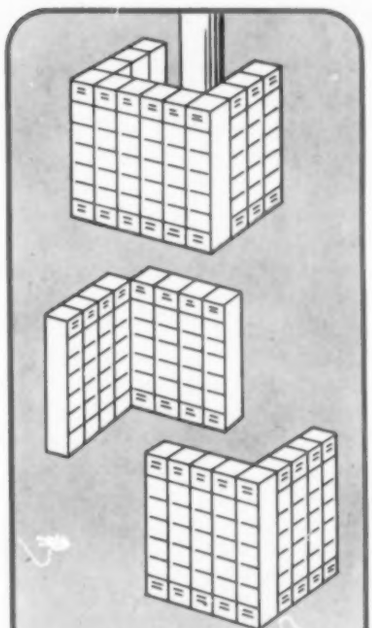

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EVERYTHING UNDER CONTROL

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ures, but there is still room and demand for much further improvement.

While the commutator has long been looked at askance, it is still the cheapest wide speed control device. This may not always be so. Development of a superior form of tube-type frequency converter might challenge its position and enable the simple induction motor to remain supreme—a desirable goal, but not immediately obtainable.

Better motor controls are needed. Control engineers, always being pushed for schemes to control more complex drives, have need for electronic tubes of vastly increased life and rating.

Semi-conductors have already invaded the industrial control field in the form of copper oxide and selenium rectifiers. These simple devices, however, do not permit the control which the grid provides in an electronic tube. However, the recently developed Transistor, using semiconductors, does permit the tube type of control.

We can look some day to the end of the present contactors with their open arcs. The need is for some form of circuit-opening device in which the arc is completely enclosed. This may take the form of a mercury switch, with an atmosphere of inert gas or perhaps a substantial vacuum.

Looking boldly to the future we see as our long-range objective a drive that is quite unlike that in any of today's catalogs. This will be a burn-out proof motor. The windings, like the ball bearings of today's Life-Line motor, will have indefinite life. Moreover it will have built into it complete thermal and overload protection, as do transformers. The motor, furthermore, will contain within it its starting equipment. It will be a packaged drive in the full sense of the term, requiring only a foundation, electrical leads to a pushbutton and power supply, and shaft connection.

LIGHTING

Discussing lighting, S. G. Hibben, director of applied lighting, sees its future stretching to remote horizons. A filament material superior to tungsten is unlikely and there is but little prospect for better gases to surround it excepting krypton or xenon, both of which are expensive.

Mechanical and metallurgical perfections will undoubtedly continue to produce improvements, but the present-day efficiency of the tungsten lamp could at most be increased by a small percentage. The three-hour photo-flood lamp leads this class, at 36 lumens per watt. The ultimate ceiling is set at the softening temperature of tungsten, just short of melting, and certainly the efficiency of this illuminant will never exceed 50 lumens per watt, because molten tungsten emits but 52.

High-pressure mercury-vapor lamps have a hopeful future because their efficiencies are already well in excess of 50 lumens per watt and may reach 100.

The discovery of a bulb material more refractory than clear quartz would be a long step toward better high-pressure mercury lamps, while another advance would be a means of utilizing the large amount of invisible ultraviolet radiation generated by the typical mercury arc.

Efficiency of today's fluorescent lamps of about 60 lumens per watt may be doubled in the next decade, through improved phosphors to provide a better transformation of ultraviolet to visible light, coupled with betterment of the inert gas mixtures within the tubes, and perfected electrodes. Superimposed upon all physical improvements is the gain that results from using alternating current at frequencies higher than 60 cycles. Furthermore, on the future horizon is glimpsed the possibility of utilizing a phosphor material (perhaps an inorganic sulphide) on walls or ceilings, or incorporated into plastics and building materials. This phosphor could conceivably absorb and later re-emit what is now the wasted ultraviolet as well as some visible portions of our present light sources.

A somewhat fantastic but enticing idea is that natural daylight can be absorbed into a species of light "storage battery," peculiar paints or dyes emitting a luminous radiation after sundown. Already known are phosphorescent materials that after exposure to almost any kind of light, and especially sunlight, glow for several hours after they have been excited.

ELECTRONICS

Electronics is still on the steeply rising curve of development, according to Walter Evans, vice president of Westinghouse electronics and X-ray divisions at Baltimore. There appears to be no absolute limit to power that can be generated with tubes. The practical limits to tube output at any one time are those of materials, which are continually being improved. Realization of large supercathodes would help make possible high-frequency generators with outputs of many megawatts and would be a large step toward high-frequency energy at less cost.

Only a few years ago a few hundred kilocycles was considered high frequency. Today tubes are available to generate frequencies up to several thousand megacycles. As yet the average powers available from these megacycle tubes is small but history promises this will be greatly increased.

At present the practical limit of tube-generated frequencies is about 30,000 mc, although 60,000 has been realized experimentally.

If generators of super-frequencies at super-powers become available, there should result increased use of present electronic functions, and development of new ones.

High-frequency heating can be expected to expand. Ability to generate r-f energy in blocks of 10,000 kw or 50,000 kw at a cost of little more than 60-cycle energy would open up whole new fields to r-f heating.

Industry has scores of metal-annealing tasks that, in the future, might be done faster or better and at acceptable overall cost with electricity (perhaps at 60 cycles or with high frequencies) instead of present fuel-fired ovens of acre size.

Television may experience some major changes from its present forms, and other forms of communication may be altered considerably.

In the future many manufacturing and assembling processes may require only nominal human attention. Information may be fed into electronic-operated computers, the integrated results causing mechanized controls to perform the pre-directed functions.

The electronics engineer is still a long way from being able to generate frequencies of visible wavelength. But who can say that some day light will not be produced by devices that convert low-frequency energy directly into visible frequency instead of indirectly as is the case at present.

NATIONAL TUBE COMPLETES EXPANSION WORK AT LORAIN

▲ Construction of National Tube Co.'s extensive new steel and pipemaking facilities at Lorain, Ohio has been virtually completed. Workmen are now putting the finishing touches on the new mills, which involve new facilities from one end of the plant to the other, from handling of raw materials to shipment of finished products.

These new facilities are considered to be a major addition to the American steel industry since the close of the war, and the project is of key importance in United States Steel's billion dollar coast-to-coast postwar improvement and development program.

Major units in the improvement program at Lorain are the world's first continuous seamless pipe mill, new blooming, bar, and billet mills, an entirely new Bessemer steel plant, 177 new by-product coke ovens, and a modern warehouse for pipe storage under roof. The new steelmaking facilities boost National Tube's rated output at Lorain to approximately 2,250,000 tons annually.

Developed by National Tube engineers, the new continuous mill is the first of its kind ever built. It eliminates several steps in the conventional method of making seamless pipe. The continuous rolling process has long been identified with hot rolled strip and sheet mills, and is being employed for the first time at Lorain to turn out long lengths of seamless steel pipe. The new mill is designed to make small size seamless pipe products ranging from two in. to four and one-half in. in diameter. The mill's rated capacity is 18,000 tons of pipe a month.

Steel rounds for seamless pipe production at Lorain, billets and slabs for the plant's buttweld pipe mills, and additional billets for other plants of United States Steel will be produced in the new blooming, bar, and billet mills. This unit includes four major mills—one blooming, one bar, and two continuous billet mills. Twenty-four modern, bottom-fired soaking pits have been installed to reheat for rolling the ingots from the bessemer and open hearth shops.

The new bessemer steel plant has three active 25-ton converters, and a fourth stand-by converter for spare use. These are the first all-welded bessemers ever built anywhere. They employ a new deoxidation process developed by National Tube engineers, which makes possible seamless production with bessemer steel.

Pipe sizes four in. and less are stocked in and shipped from the new, quarter-mile long warehouse. Storage capacity is 40,000 tons, with facilities for handling several hundred different standard pipe items. The assembly-line set-up of the warehouse is designed to speed up shipment of customers' orders, particularly on less-than-carload shipments of mixed sizes, and 72 railroad cars can be loaded from it daily.

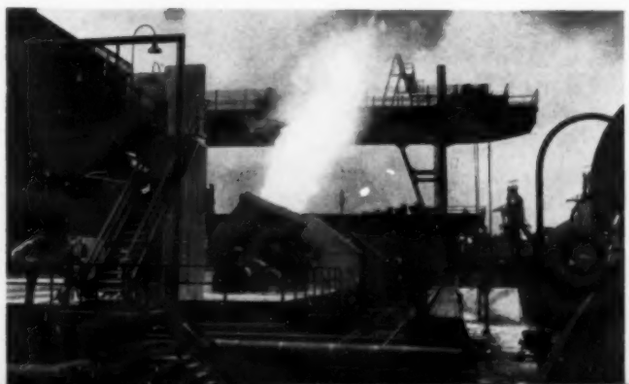
Coke production at Lorain has been doubled with the installation of three new batteries of by-product coke ovens. Each battery has 59 ovens. Along with four older batteries of 52 ovens each, these facilities can now produce 1,650,000 tons of coke annually. The improvements also include enlargement and modernization of coal and coke handling facilities, numerous changes in the facilities for recovery of coal chemicals, and a coal and coke laboratory.

All of National Tube's buttweld pipe production has been concentrated at Lorain, and new galvanizing facilities for buttweld pipe have been installed.

Major improvements have been completed at the plant's ore docks on the Black River, where the largest vessels engaged in ore shipping on the Great Lakes can be unloaded. Two new ore unloaders have replaced two smaller unloaders and the entire dock was rebuilt.

The Lorain improvements include 25 miles of new railroad tracks. More than 250,000 cubic yards of concrete were poured for building foundations, new roadways, and other uses. More than 1900 carloads of new machinery and equipment have been installed. The new mills required 51,300 tons of structural and reinforcing steel. More than 500 miles of piping have been installed for water, steam, air, electricity and other utility transmission lines.

The National Tube Co. has put into operation this and three companion new bessemer converters while workmen put finishing touches on other new construction in a multi-million dollar program of steel and pipemaking facilities.



New in pipemaking is this world's first continuous seamless pipe mill constructed at Lorain Works of National Tube Co. This is a general view of the hot end, where heated, solid round pieces of steel speed through a non-stop process to emerge as seamless pipe.

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Date-line Diary...

November 1

▲ The CIO United Steel Workers at five plants of the Allegheny Ludlum Steel Corp. went out on strike today.

▲ United Steel Workers and the Bethlehem Steel Co. came to an agreement yesterday under which the workers will be provided with a minimum pension of $100.00 a month provided they have twenty-five years service at age of 65. The pension plan will cost about 12¢ an hour and the contract runs until December 31, 1951, although the union may reopen it on wage rates only, on December 31, 1950.

November 2

▲ The Budget Bureau predicts that the United States Government will run $5,500,000,000 into the red during the present fiscal year because of a decline of $3,000,000,000 in income and because of spending $1,600,000,000 more than originally estimated. The original deficit had been $900,000,000.

▲ The CIO Steel Workers settled their strike with the Cooper Bessemer Corp. of Mt. Vernon, Ohio and the Rotary Electric Steel Co. of Detroit today.

November 3

▲ Department of Commerce stated that new construction put in place in October was $1,856,000,000. In the first ten months of 1949 new construction put in place was $15,882,000,000 or up $200,000,000 from one year ago.

▲ The Detroit Steel Corp. announced that it would acquire the Portsmouth Steel Corp. next January. They plan to expand the present facilities at Portsmouth.

▲ Crucible Steel Co. announced a 20 per cent pay cut for all salaried employees because of the steel and coal strikes.

November 4

▲ The Phelps Dodge Corp. raised the price of copper 7/8¢ to 18 1/2¢ a lb.

▲ American Railway Car Institute announced that freight car deliveries during October totaled 4,532. New orders totaled 201 and the backlog as of November 1 was a total of 9,783 compared with 111,405 a year ago.

November 5

▲ L. C. Paulson, trial attorney for the FTC announced that major steel companies have agreed to terms for settling the anti-trust suit against the steel industry. The proposed settlement will permit steel companies to absorb freight charges if the practice does not lessen competition. A Supreme Court test may be required.

▲ The Lone Star Steel Corp. announced that it will build a cast iron pressure pipe plant which will cost $1,000,000 at Lone Star, Texas.

November 6

▲ The F. W. Dodge Corp. estimates that building and construction volume in 1950 will be 4 per cent below 1949's estimated total of $9,940,000,000 in the thirty-seven states east of the Rocky Mountains.

November 7

▲ The Apollo Steel Corp. at Apollo, Pa. reopened today. This plant which is equipped with hand sheet mills will get back in production because of the shortage caused by the strike.

▲ The Lone Star Steel Corp. has announced that it will build a steel mill in eastern Texas, whose estimated cost is $52,500,000 and will include four open hearth furnaces with an annual capacity of 500,000 tons, a 110-in. slabbing mill, a four-high, 72-in. hot strip mill, and a line to make electric weld pipe.

▲ The Bethlehem Pacific Coast Steel Corp. will start construction of a new structural steel fabricating plant in Seattle.

▲ C. Cox, president Carnegie-Illinois Steel Corp., agreed to provide 50,000 tons of coal to help Pittsburgh in its coal shortage.

▲ Based on reports of companies having 94 per cent of capacity of the steel industry, the operating rate of the steel industry is scheduled to be 21.0 per cent of capacity for the week beginning November 7, 1949. This is equivalent to 387,000 tons of steel ingots and castings compared with 162,000 tons one week ago.

November 8

▲ The General Motors Corp. voted a year end dividend of $4.25 per common share which brings 1949 payments up to $8.00.

▲ The Republic Steel Corp. and the Jones and Laughlin Steel Corp. signed with the CIO on an agreement very similar to the Bethlehem plan.

November 9

▲ Scrap prices moved up $2.00 a ton and number 1 heavy melting scrap sold at $30.00 in Chicago and at $25.00 in Philadelphia.

▲ John L. Lewis stopped the 52 day old soft coal strike and ordered the men back to work until November 30, at which time they are to go out again if an agreement has not been made.

▲ The Youngstown Sheet and Tube Co. signed with the CIO a plan similar to the Bethlehem plan.

November 10

▲ The F. W. Dodge Corp. announced that contracts awarded in October in the thirty-seven states east of the Rockies totaled $1,061,751,000 or the third largest monthly volume in Dodge report history.

▲ The Department of Commerce reported that business inventories rose $150,000,000 in September for the first gain since November 1948.

▲ The Pennsylvania RR awarded contracts for 226 diesel electric locomotives which will cost $38,000,000.

November 11

▲ Steel production in Western Germany dropped in October for the third month in a row and is now 17 per cent below August production.

▲ The Lake Superior Iron Ore Association estimates stocks at furnaces and on the docks on November 15th is about 46,000,000 tons which should be enough to carry through the closed season.

▲ United States Steel Corp. signed with the CIO on a plan very similar to the so-called Bethlehem plan.

▲ The directors of the American Arch Co. announced that they have decided to liquidate the corporation because of declining business and supply of fire brick.

▲ The Inland Steel Co. announced that it had signed with the CIO. The settlement provides two pension plans, one similar to the Bethlehem formula and the

other in line with the plan which the company has had for a number of years.

November 13

▲ The Wheeling Steel Corp. signed with the CIO on a plan similar to the Bethlehem plan.

▲ The Babcock and Wilcox Tube Co. signed an agreement which ended their strike at their Beaver Falls plant.

November 15

▲ The Texas Eastern Transmission Corp. asked the Federal Power Commission for authority to construct additional pipe line facilities which will provide utilities in the New England area with as much as 200,000,000 cu ft of natural gas per day by 1951.

▲ J & L Steel Corp. declared a cash dividend of 65¢ a share on common stock payable January 1st, 1950.

▲ Based on reports of companies having 94 per cent of capacity in the industry, the operating rate of the industry is scheduled at 54 per cent of capacity for the week beginning November 14, 1949. This is equivalent to 995,500 tons of steel ingots and castings compared with 387,000 tons one week ago.

▲ Sixty eastern railroads were granted a 12½ per cent increase in passenger fares by the ICC.

▲ The Commerce Department stated that personal income in the United States during September was at an annual rate of $210,800,000,000 and for the first nine months of this year was at an annual rate of $212,300,000,000.

November 16

▲ The J & L Steel Corp. rescinded the pay cut order which had been put into effect for salaried employees during the latter part of the strike.

▲ The Aluminum Co. of America signed with the AF of L aluminum workers for the employees at three plants. Nine other plants covered by the CIO are still on strike.

November 17

▲ The Republic Steel Corp. open hearth plant at Youngstown, Ohio was shut down by a strike of eleven charging machine operators.

November 20

▲ Armco signed an agreement with the CIO for the workers at six of its plants, which was similar to the Bethlehem pattern.

November 21

▲ Based on reports from companies having 94 per cent of capacity of the industry, the operating rate of the steel industry is scheduled at 78.2 per cent of capacity for the week beginning November 21, 1949. This is equivalent to 1,441,600 tons of steel ingots and castings compared with 1,058,200 tons one week ago.

▲ The Acme Steel Co. signed with the CIO on a plan similar to the Bethlehem plan.

November 22

▲ New construction in October amounted to $1,856,000,000 or a record for the month.

November 24

▲ Charles E. Wilson, president of General Motors Corp. estimates that his company will turn out 2,750,000 cars and trucks in the United States and Canada for a new record.

November 25

▲ According to the AMA automobile companies in the United States sold more cars and trucks and buses in the first ten months of 1949 than in any previous full year. Sales amounted to 5,430,093 units.

November 26

▲ The National Tube Corp. announced that its expansion and modernization program is now nearing completion at Lorain, Ohio. The new steel making facilities boost the rated output at Lorain to about 2,250,000 tons annually, and includes complete additional facilities for the production of pipe.

November 27

▲ An American firm, the Iron Ore Co. of Canada, will join Canadian interests in the development of Quebec and Labrador iron ore. It will pay $5,000,000 for exploration and development of transportation facilities during 1951. Among the companies involved are Republic Steel Corp., Armco Steel, Wheeling Steel, National Steel, Youngstown Sheet and Tube Co., and the Hanna Coal and Ore Corp.

November 28

▲ Based on reports of companies having 94 per cent of capacity for the industry, the operating rate of the steel industry is scheduled at 87.7 per cent of capacity for the week beginning November 28, 1949, and this is equivalent to 1,616,800 tons of steel ingots and castings compared with 1,441,600 tons one week ago.

▲ A new joint contributory insurance program was agreed upon between the Weirton Steel Co. and the Weirton Independent Union, Inc. The company will pay 60 per cent of the cost and the individual employee 40 per cent of the cost. The new insurance program is a package which includes life insurance, sickness and accident insurance, and hospital and surgical benefits.

▲ The stockholders of the Detroit Steel Corp. approved the directors proposal to acquire the physical assets and steel business of the Portsmouth Steel Corp.

▲ The Board of Directors of the Pittsburgh Steel Co. deferred on preferred dividends because of the steel and coal strikes.

▲ Sharon Steel Corp. raised steel prices $5.00 a ton. The company stated that the pension insurance contract just negotiated was not a factor, but the rise was due to costs of raw materials.

▲ The Bureau of Labor Statistics stated that living costs dropped 0.6 per cent between mid-September and mid-October bringing it up to a level of 168.5 per cent.

▲ C. H. Buford, president of the Milwaukee RR testified before the ICC that the railroads must spend $2,000,000,000 to repair the damage caused by the heavy freight traffic of World War II.

November 29

▲ The estimated total bookings of fabricated structural steel for October according to the AISC totaled 158,120 tons, the highest for 1949. Shipments in October dropped to 95,350 tons. Because of the strike the backlog increased to 583,580 tons.

November 30

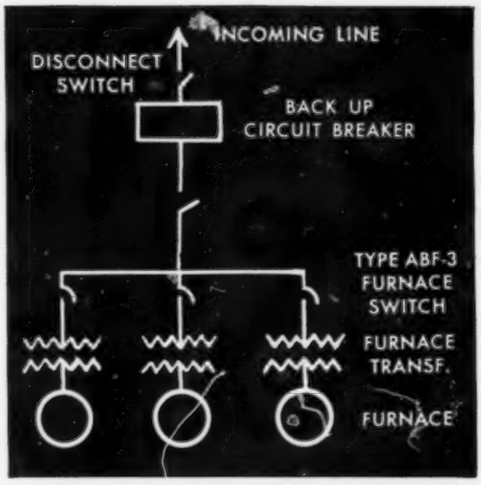
▲ The Board of Directors of the Inland Steel Co. declared a year end cash dividend of $1.00 per share.

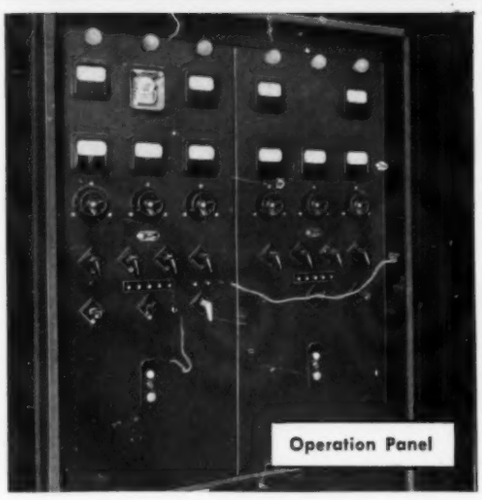
▲ The Follansbee steel Corp. raised prices $35.00 a ton on all grades of silicon sheets.

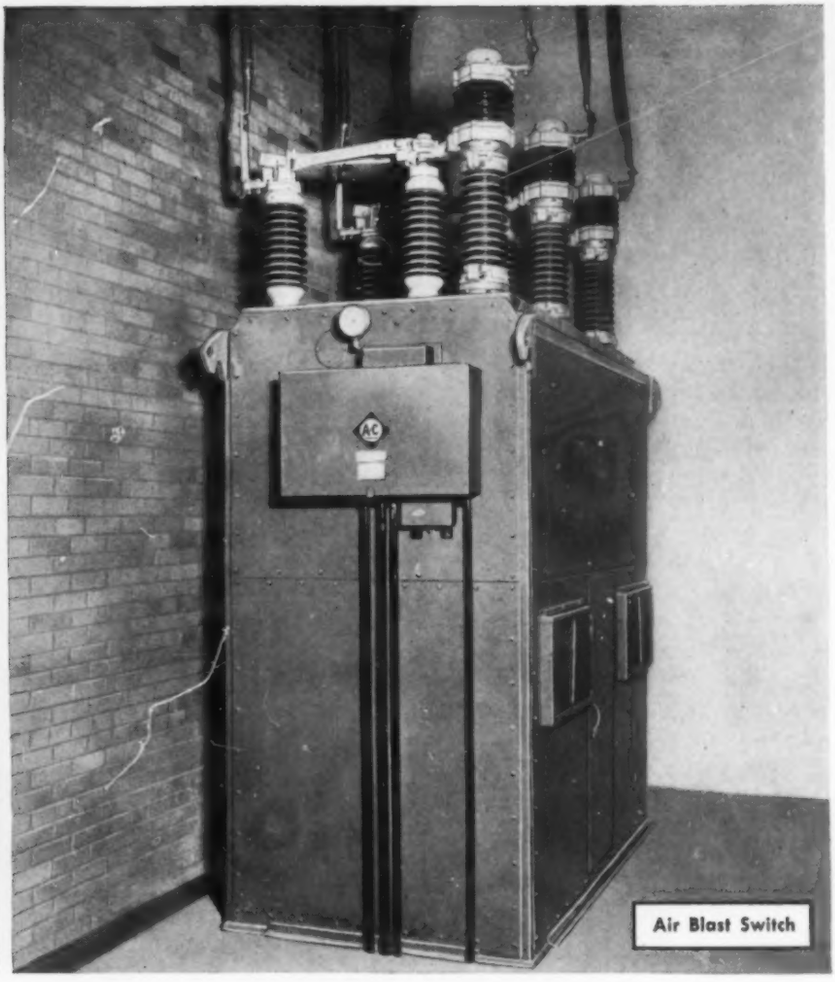
▲ Secretary Snyder announced new financing plans which will refund $10,000,000,000 of the public debt.

▲ The United Mine Workers went on strike tonight. This strike was called off on December 1st when Mr. Lewis announced a resumption of the three day work week.

▲ Scrap prices dropped in Pittsburgh to $32.00 a ton which was a decline of $1.00 to $2.00 from recent quotations.




Operation Panel


Air Blast Switch

Protect Arc Furnace Output with A-C Air Blast Switch

FURNACE HEAT INTERRUPTIONS ARE COSTLY. Eliminate them with the switch *especially designed* for arc furnace duty. The Allis-Chalmers ABF-3 Arc Furnace Switch is the *proven* answer for the repetitive, heavy duty switching met in arc furnace service.

This switch gives *thousands of operations* with little or no maintenance . . . proven by *both* test and years of operating records! It is built in ratings of 600 and 800 amperes, for service up to 23 kv.

Liberally Designed and Built

Liberal design and construction keeps costly shutdown for inspection and maintenance to the absolute minimum. Contact maintenance is negligible since the air blast principle of arc interruption reduces arcing time to *one cycle or less*. Also important is fast circuit interruption, consistently within 4 or 5 cycles.

The ABF-3 is built with quality components. Porcelain insulators of 34.5 kv rating, low inertia parts and special contact snubber units further contribute to the dependable performance of this rugged switch.

Complete Ready-to-Operate Unit

The Allis-Chalmers ABF-3 air blast switch is a *complete* unit, ready to install and operate. All electrical controls and air generating and storage equipment are in the dust-proof metal cubicle at right. Remote control equipment is in furnace operation panel at left.

There is a qualified steel mill representative near you, ready to explain how this Arc Furnace Switch can be applied profitably to *your* operations. Call your nearest A-C sales office or write direct. A-2899

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Ohio Magnets lift efficiently—*uniformly*—over extended periods of operation because they operate *cooler*. Copper coils are heavier-duty, carefully sealed with plenty of non-cracking asphaltum.

Uniform lifting capacity is one of the reasons why more mills are standardizing on Ohio. Satisfy yourself. Send your next order to Ohio—*25 years a leader in magnetic materials handling.*

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A-3027

Industry News...

NEW ENGLAND STEEL PLANT IS UNDER CONSIDERATION BY LARGE GROUP

▲ The New England council, a group of about 2,400 corporations and individuals, organized a special steel committee in December, 1948 to investigate the possibility of building a large steel mill in New England. Recently, this committee met and discussed the establishing of a steel mill capable of turning out 1,250,000 tons of ingots annually and processing 1,000,000 tons of finished steel, hot and cold rolled sheets, hot rolled bars and light plates. The mill would require approximately 2,000 acres of waterfront land and employ between four and five thousand workers.

The method of financing this mill is "novel." The New England state chosen for the site would create by law a new public authority, similar to the Port of New York Authority. This organization would raise money by issuing bonds, exempt from federal taxes, at a low interest rate. It is estimated that the cost of the mill would be around $225 million. According to the plan, when the mill is erected it will be rented to a privately owned operating company, for which the name New England Steel Corp. has been proposed. The rent would be high enough to service the long-term bonds, amortize them in full by maturity and pay the expenses of the authority.

It is estimated that New England consumes 4,100,000 tons annually of carbon steel, and another 1,000,000 tons of alloy steel (the projected mill does not contemplate making alloy steel). Within 200 miles of any likely site of the mill is 7,000,000 tons of annual carbon steel consumption. That includes eastern New York and northern New Jersey, and a moderate quantity for export.

It is expected that iron ore from the proposed plant furnaces might eventually come from the rich New Labrador deposits now being explored. Newfoundland, Venezuela and Chile are mentioned as alternative sources. Some ore has already been offered from as far away as Spanish Morocco.

Coal could be unloaded from ships out of Hampton Roads or Newport News, Va. Over 1,000,000 tons annually would be required and the committee claims it knows where two contracts could be quickly placed for 500,000 tons each.

Limestone occurs widely in New England, but varies considerably in chemical make-up. The committee is now studying the nature and extent of the variation, and is convinced limestone could be obtained either in New England or near seaboard in New Brunswick, Canada.

GRANITE CITY STEEL BUYS OXYGEN GENERATORS

▲ Granite City Steel Co., of Granite City, Ill., has concluded arrangements with Air Products, Inc. for the installation of oxygen generators. The generators will extract oxygen from the air for use in the Granite City firm's operations. N. P. Veeder, vice president in charge of operations of Granite City Steel Co., reports that the generators proposed for the company are the "most modern and economical means of supplying the mill's oxygen requirements." Mr. Veeder also stated that his company is working on a process which will use the generators' by-product, nitrogen, in certain steel making operations.

PENNSYLVANIA STUDIES POLLUTED AIR PROBLEM

▲ Pennsylvania has launched an intensive program to study the problem of polluted air. Dr. Norris W. Vaux, secretary of the Department of Health, announced plans for a statewide program to determine the effects of polluted air on the public health. This program will be undertaken by the Bureau of Industrial Hygiene under the direction of Dr. Joseph Shilen, bureau director. A special division of the bureau has been established to concentrate on the problem.

The principal means of attack in the campaign will be a unique mobile field laboratory now being built for the bureau at the Mine Safety Appliances Co. This laboratory will be equipped with scientific instruments and devices to sample and analyze atmosphere suspected of containing harmful or annoying gases or dusts. It will be ready in about two months.

The new air pollution division, with headquarters in Harrisburg, Pa., will be headed by J. S. Sharrah, presently stationed at the Industrial Hygiene Bureau's Pittsburgh laboratory.

Because air pollution is relatively new in the science of public health, there are a limited number of experts in the field, Dr. Shilen said. Mr. Sharrah has done considerable research on air pollution.

The new laboratory will be the only one of its kind in this country. Besides containing all the necessary equipment for taking air samples, the field laboratory will provide facilities for on-the-spot analytical studies of many industrial hazards. Further tests also will be made at the bureau's permanent laboratories in Harrisburg, Philadelphia, Pittsburgh, Williamsport, Scranton, Altoona and Erie.

Air pollution surveys will be made by the "air detectives" with the mobile laboratory at the request of in-

BLAW-KNOX BUILDS NEW ADMINISTRATION BUILDING

Part of the recent modernization work of the Blaw-Knox Co. has been the construction of a $500,000 administration building for its largest manufacturing division, located at Blawnox, Pa. Approximately 1500 people are employed by this division. The recently completed building, 60 by 140 ft, provides needed office quarters for engineering and executive personnel. It has also permitted the razing of some old quarters to provide room for expansion of manufacturing facilities.

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BY THE TON

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You control your own supply and remove the risk of costly shut-downs which often result from delivery failure.

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dustrial plant managements, civic groups and municipal or county officials.

The mobile laboratory will have its own power-generating plant and heating system because many surveys and studies have to be made away from a power supply source. In some instances, laboratory analysis must take place immediately after the air sample has been obtained since chemical changes might destroy the sample.

One of the important instruments in the field laboratory will be a Mine Safety electrostatic dust and fume sampler. With this device, precise quantitative samples of dusts, fumes and smoke can be taken from atmospheres in factories or industrial areas.

Air-borne particles are deposited on the inner surface of a collecting cylinder where they are available for analysis by weight, count, chemical or radiological study.

At the bureau's main laboratory in Harrisburg, a spectograph will be employed to identify samples of air-borne dusts by type and location. Another instrument in the field laboratory will be an indicator to determine concentrations of hydrogen sulphide in the air. One of the most toxic of the more common industrial gases, hydrogen sulphide is harmful in extremely low concentrations. Other instruments include special detectors for sulphur dioxide, carbon monoxide, nitrogen dioxide and benzol. There also will be devices for checking the explosibility and flammability of gases and vapors. One unique device, called an osmoscope, will be employed to detect and identify odors.

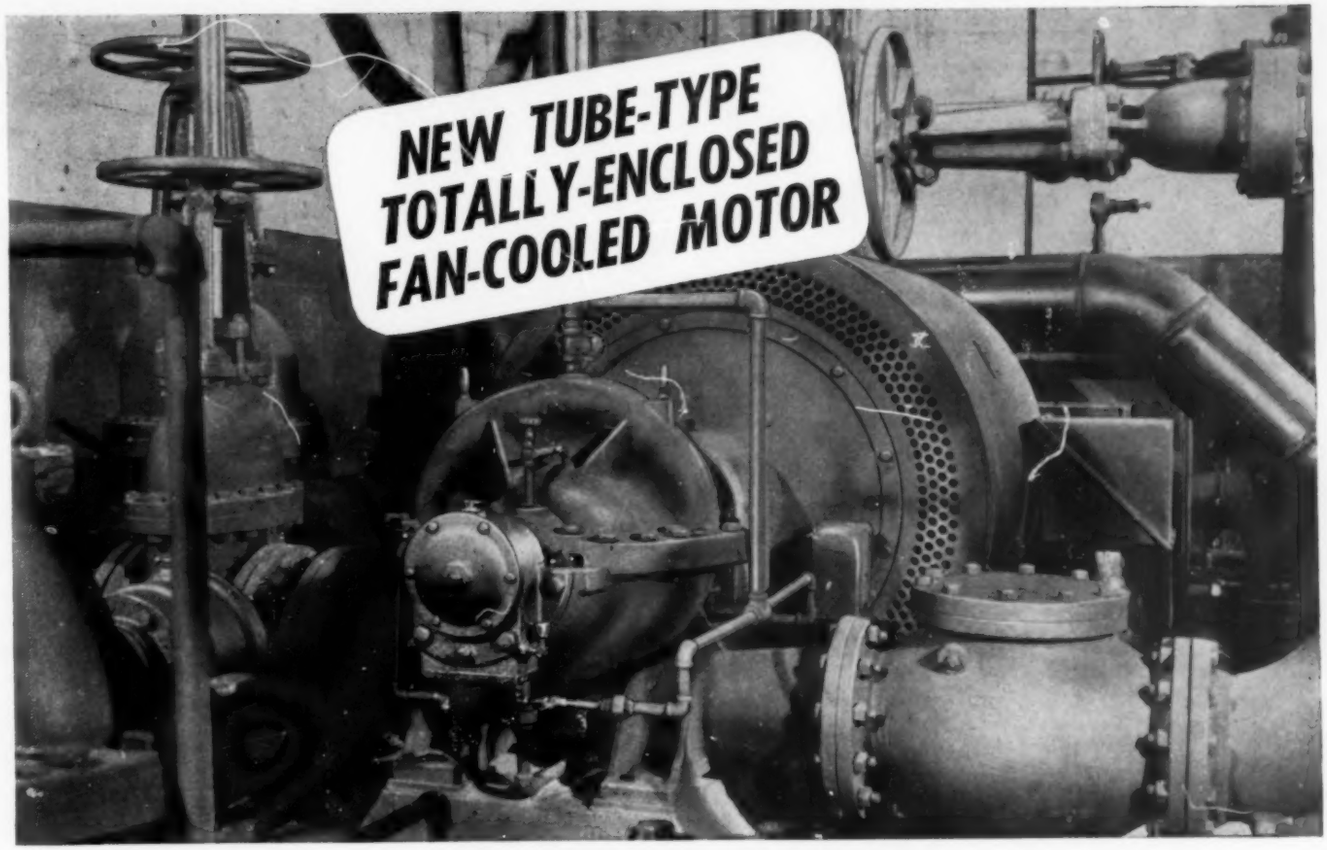
Because weather conditions are important factors in air pollution, a complete set of meteorological instruments will be used by the field laboratory staff in the surveys.

A HINT FOR SNOW REMOVAL . . .

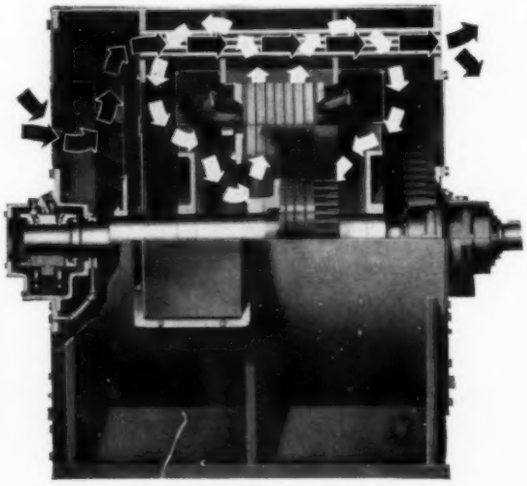
Here's an ingenious-but-practical method of removing snow from plant yards, area-ways, shipping docks, etc. Not only can snow be removed speedily by this application of the crane truck, but special shoveling crews are eliminated, extra snow-removal equipment and operators are not required, and another use for existing plant equipment is found.

Construction of the snow-shoveling attachment is simple. The unit comprises (1) a large welded-steel scoop, and (2) a rig for mounting the scoop to the truck. The rigging comprises a structural-steel "A"-shaped element, two lengths of chain, and a piece of iron pipe. The "A"-shaped element is pinned, at the narrow end, to the base of the boom of the Yale crane truck. The scoop is pinned between the legs of the "A." The chain, with the pipe used as a spreader, supports the "A" structure and scoop from the top of the boom.

In operation, the boom of the Yale truck is lowered until the scoop rests on the ground, and the truck moves forward until the scoop fills with snow. The boom is lifted to lift the bin, and the truck swings or transports the load to the dumping area. To dump, the crane-hook is engaged with an eye welded to the back of the bin, and the hook is raised.



Tight Corners, Tough Spots Call for Tube-Type Motors



THIS 350 HP TUBE-TYPE, totally-enclosed, fan-cooled motor is really backed into a corner in the below-ground-level pump house of a midwestern steel mill. Space is at a premium, heat is high, and ventilation and accessibility for maintenance are poor.

It's a spot for the Allis-Chalmers tube-type motor, built with tight corners in mind. It's designed especially for extreme conditions of dust, dirt, fly ash, rain and snow, smoke, and corroding fumes. Three years of successful operation in industry's toughest spots have proven this motor.

The unique cooling system (shown at left) of the tube-type motor reduces maintenance to a point never before reached in totally-enclosed motor design. Sizes from 75 hp to several thousand hp. Also built in explosion-proof models. To fit this motor into *your* tight corner, call your nearest A-C sales office. Or write direct for Bulletin 05B7150. A-2820

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ALLIS-CHALMERS

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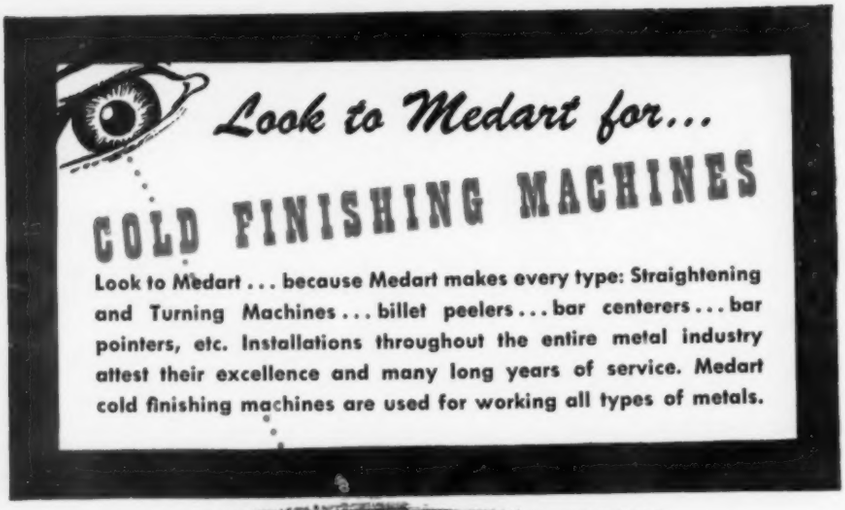
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Look to Medart . . . because Medart makes every type: Straightening and Turning Machines . . . billet peelers . . . bar centerers . . . bar pointers, etc. Installations throughout the entire metal industry attest their excellence and many long years of service. Medart cold finishing machines are used for working all types of metals.

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HYATT BEARINGS BUILDS EXTENSION TO PLANT

▲ Hyatt Bearings Division, General Motors Corp., announced that work has commenced on a 125,000 sq ft extension to their second plant in Clark Township, N. J.

The original New Jersey plant in Harrison has been producing roller bearings for automotive, agricultural, industrial and railroad applications for over 50 years. Then in 1942 when the increased war demand for anti-friction bearings taxed the Harrison facilities to capacity this second plant was acquired.

Exclusively devoted to the manufacture of aircraft engine roller bearings during the war, this plant has since been utilized for the production of automotive bearings and railroad roller bearing journal boxes.

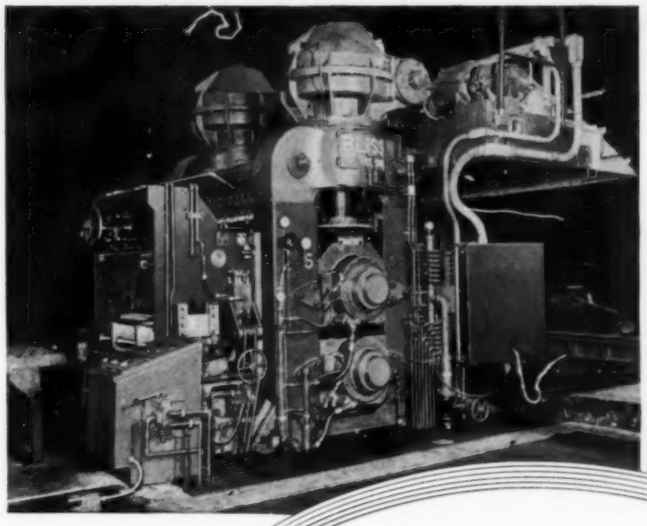
Now increased post-war demand for Hyatt roller bearings have made additional manufacturing space necessary and this expanded plant area is expected to be ready for occupancy shortly after the first of the year.

Designs call for the most modern type of industrial building construction with steel frame masonry, an insulated roof and forced ventilation. Like the present plant the new extension will be mainly a one story structure with a second floor across one side as a continuation of the existing mezzanine arrangement.

NEW FIRM TO SPECIALIZE IN METALS RESEARCH

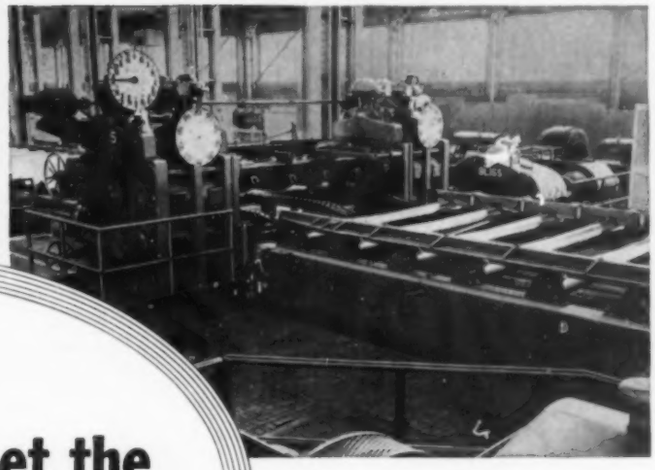
▲ The establishment of a new firm specializing in research and consulting has been established in Cleveland, Ohio, will be known as Metals Research Associates. Service is being offered in the fields of casting, forming and heat treatment of metals, plant processing design, and general problems concerning physical metallurgy.

Dr. Sachs, well known as pre-war department head at the Kaiser Wilhelm Institute for Metals Research in Germany, founder and director of the Laboratory for Mechanical Metallurgy at Case Institute of Technology, will head up this group. Others interested in the firm are Dr. H. P. Croft, director of research for the

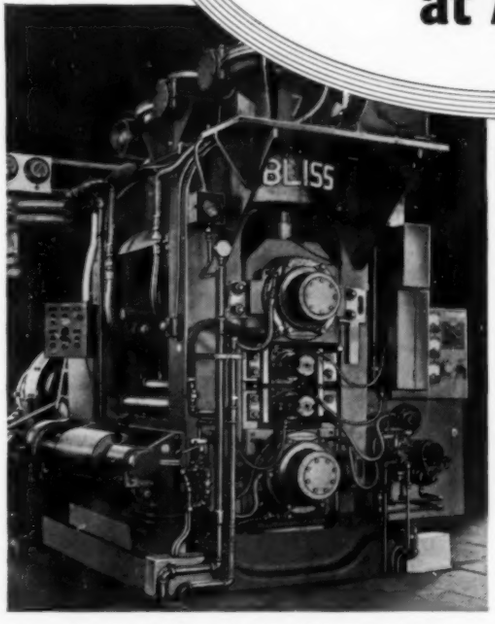


60" Two-High mill at the Alcoa Davenport, Iowa, plant.

Bliss side trimmer and scrap chopper in Davenport's hot mill line capable of trimming stock up to 1" thick by 136" wide.



BLISS Rolling Mills meet the test of severe usage at Alcoa



34" Four-High mill, one of four installed at Alcoa's Edgewater, New Jersey, plant.

Whether it's strip, sheet or foil, hot or cold working, you will find Bliss Rolling Mills and Accessories meeting exacting standards throughout the various plants of the Aluminum Company of America.

The 4-high mill illustrated here is one of a variety of Bliss rolling mills used at Alcoa's Edgewater, New Jersey, plant, principally to roll aluminum foil from .040" thick stock, at speeds up to 1500 feet per minute. At its Davenport, Iowa, plant, Alcoa relies on a Bliss 60" single-stand 2-high mill for rolling specialty sheets and temper pass rolling on the lighter gages. Another Bliss 72" single-stand 4-high mill is used for general purpose reduction. Reductions of as much as 60% are regular on this mill although 50% is normally considered a good average.

Bliss auxiliary equipment like the side trimmer and scrap chopper illustrated is also installed in this plant.

With non-ferrous and ferrous metal producers alike, Bliss Rolling Mill engineers concentrate on the design of equipment, combining the speeds and controls required with the rigidity and accessibility necessary for long trouble-free service.

For the engineered refinements that mean maximum production—for rugged rolling mill performance, consult Bliss. You will get the same dependable counsel that has made Bliss the first name in power presses for more than 90 years.

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Rolling Mill Division
Salem, Ohio

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midwest division of Chase Brass and Copper Co., until his recent appointment as vice president of Wheeling Bronze Casting Co.; Lee Wilson, founder of the Lee Wilson Engineering Co.; C. F. Prutton and Associates, technical and consultant firm in Cleveland, will supply an experienced staff and facilities for chemical phases of research. G. B. Espey, vice president of Metals Research, was formerly assistant to Dr. Sachs at Case and metallurgists for the Lee Wilson Engineering Co.

The research facilities of this new firm are in Cleveland, the metallurgical laboratories at 20005 West Lake Road, and the chemical facilities at 2310 Superior Ave. Equipment is available for most types of heat treatment, X-ray diffraction, metallographic study, and common methods of testing. Consulting and research is also presently being done for some of the nation's leading concerns in the steel industry.

WELDED PIPE MILL TO BE BUILT IN TEXAS

▲ Contracts for design and construction of the 150,000 sq ft large-diameter welded steel pipe mill to be erected for A. O. Smith Corp. at Houston, Texas have been awarded to Austin Co., which has already started work on the foundations. A. O. Smith Corp. and Armco Steel Corp., whose Texas subsidiary, Sheffield Steel Corp., will supply the steel for pipe production from its adjacent mill, will be co-owners of the new plant, which is to be operated by A. O. Smith Corp. of Texas. It will have a production capacity of approximately 35,000 tons a month in sizes ranging from 8⅝-in. pipe for oil well casings to 30-in. and larger oil and gas line pipe, and will be the second largest source of such pipe, exceeded only by the A. O. Smith Corp.'s headquarters plant in Milwaukee.

Clearance of 33 ft will be maintained below the trusses in the plant. It will have two 80-ft craneway aisles—each equipped with two 20-ton cranes—and an intermediate 40-ft aisle, all extending the full length of the plant—675 ft. A pickling building, 200 x 80 ft, adjoining the larger structure, will be equipped with a 40-ton crane, which will also serve a 330-ft crane runway.

Trusses of standard H-section welded design are being used throughout the plant, which will require 1300 tons of structural steel. It will be enclosed with alternate bands of corrugated asbestos and steel sash above a 6-ft masonry sill wall, and will have a precast concrete roof.

A 40 x 200-ft steel frame and masonry air conditioned office building is also included in the contract.

COKE OVEN BATTERY COMPLETED BY REPUBLIC

▲ Completion of a new battery of 38 coke ovens at Republic Steel Corp.'s Youngstown, Ohio, district steel plant was announced recently as the first coke was pushed from the battery.

Construction of the new battery is a major step in the modernization of Republic's coke making facilities in the Youngstown district and another important step in improvement of its coke making facilities in the Mahoning Valley area. The new battery replaces one of four older batteries.

Construction of a second battery of 65 ovens is already underway. It will replace two of the remaining three old batteries.

Republic recently completed construction of a new battery of 40 coke

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SAVES acid and metal
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INSURES brighter, cleaner surfaces.

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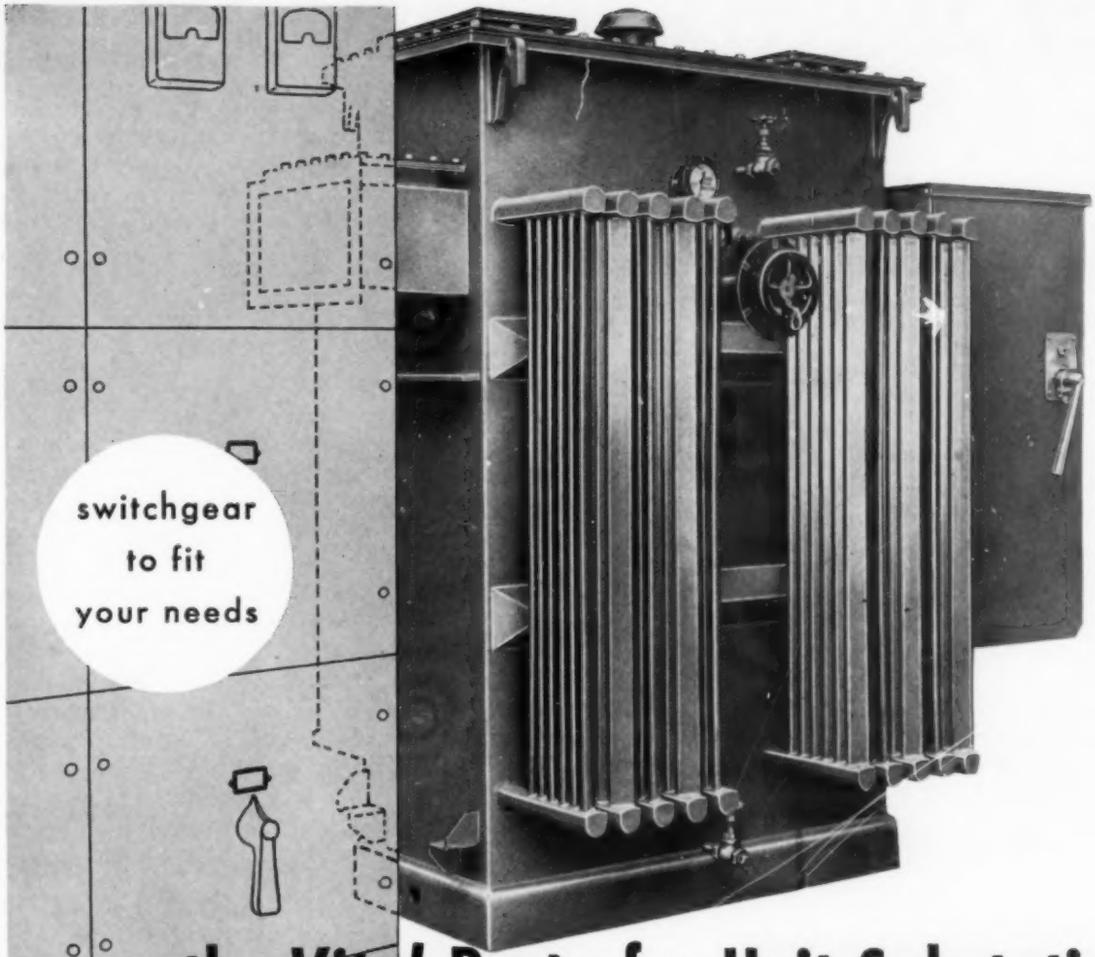

the *Vital* Part of a Unit Substation is the Transformer

• Wagner Unit Substation Transformers can be Throat Connected to any make of Switchgear...The transformer is the vital part—the fuel pump—of a load center distribution system. If the transformer fails, the entire system is dead, whereas only part of the distribution system may be affected by the failure of a switch or circuit breaker.

You can be sure of a dependable continuous flow of power from a Wagner transformer and you can be sure that it has been carefully designed to meet your distribution requirements.

Wagner unit substation transformers with incoming high voltage switch sections to meet your requirements, and with proper throats on the secondary side for connection to any make of switch-gear, are available in the usual range of ratings up to 2000 kva. Our factory-trained sales engineers are well qualified to recommend the various combinations necessary to handle your unit substation requirements and will gladly give you immediate service.

Wagner unit substation transformers are installed in numerous electric generating stations and in all kinds of industrial plants including synthetic rubber, petroleum, steel, chemical, aircraft, automotive, paper, and many others. The importance of the transformer in a unit substation justifies calling in the Wagner sales engineer to help solve all your load center problems.

Our free bulletins TU-13 and TU-56 describe the design and construction features that make Wagner liquid-filled and dry-type unit substation transformers outstanding.

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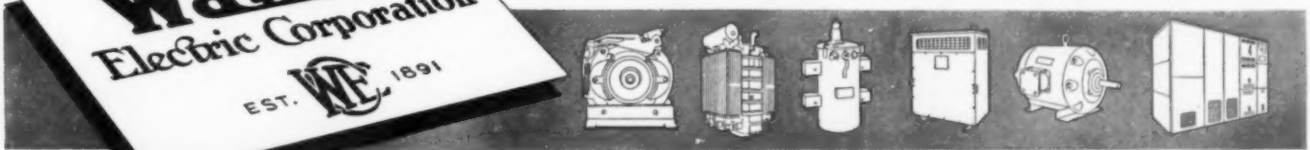
Consult Wagner Engineers on All Transformer Problems



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149-11A

ovens at its Warren, Ohio, district plant and a second battery of 40 ovens is under construction. These two new batteries replaced 64 old ovens. In addition, Republic recently purchased the RFC battery of 61 ovens at Warren and is continuing to operate these.

ANNEALING FURNACE BUILT AT ALABAMA PIPE

▲ An annealing furnace, to serve the Alabama Pipe Co.'s new plant for the manufacture of centrifugally cast iron water pipe, has recently been completed at Anniston, Ala., by Rust Furnace Co., Pittsburgh, Pa.

The furnace, a continuous conveyor type, has a capacity of 100 tons of pipe in eight hours. It is designed for heat treatment of pipe from four to 24 in. in diameter in lengths up to 18 ft 4 in.

Pipe will be heated to a maximum temperature of 1725 F upon entering the triple-zone furnace, with a gradual reduction in each zone so that at discharge it will not be in excess of 1200 F.

Furnace zones are separated by hanging curtain walls of interlocking refractory brick, in addition, there is an alloy curtain, capable of withstanding temperatures in excess of 2000 F, at the furnace entrance to reduce air infiltration.

Overall length of the furnace is 62 ft and the inside width is 21 ft. Its burners can be fired with either natural gas or lightweight fuel oil.

PITTSBURGH GEAR ACQUIRES IOWAN PLANT

▲ Announcement is made of the acquisition of the controlling interest of the 82 year old Ottumwa Iron Works, Ottumwa, Iowa by the Pittsburgh Gear Co. of Pittsburgh, Pa. Lou Mervis becomes president of this pioneer manufacturer of speed reducers, sykes-herringbone gears, hoists and other products. Other new officers for the Ottumwa concern include: E. R. Phillips, vice president in charge of sales; Francis Knuth, vice president; Myra Mervis, treasurer, and John Thurlow, secretary.

WEIRTON SETS RECORD FOR OPEN HEARTHS

▲ A new all-time world's record for steel production by 12 stationary open hearth furnaces in a single month was established in October by the Weirton Steel Co. with an output of 200,379 tons of ingots.

The previous record month was March 1949 when Weirton's open hearth output was 182,772 tons.

A new plant record also was established in October by Weirton's three blast furnaces which produced a total of 124,134 tons of pig iron during the month.

The huge production of raw steel in the open hearth department made it possible for all departments of the company in Weirton and Steubenville, Ohio, to break previous records and, consequently, October was a record month for the shipment of finished products.

Production of more than 200,000 tons of ingot steel required the consumption of more than 850,000 tons of raw materials which included iron

WELDCO
MECHANICAL PICKLER

CUTS PICKLING COSTS 35% AT CANADIAN DRAWN STEEL COMPANY

● Shown here in the "down" position is a Weldco Mechanical Pickler in the plant of the Canadian Drawn Steel Co., Ltd., Hamilton, Ontario. This 5-ton Bar Pickler pickles 15 to 20 tons of rounds, hexagons, squares, and flats per hour, in lengths up to 35 feet. Easy to operate and control, it saves 25% pickling time, eliminates the need of an overhead crane for agitation, and increases tonnage with reduced manpower.

Weldco Mechanical Picklers are also available for pickling coils, tubing, and sheets . . . can be built to any capacity, to fit any type of plant. Why not find out how Weldco can save manpower, maintenance, and money for you? Write today for further information and descriptive literature.

●

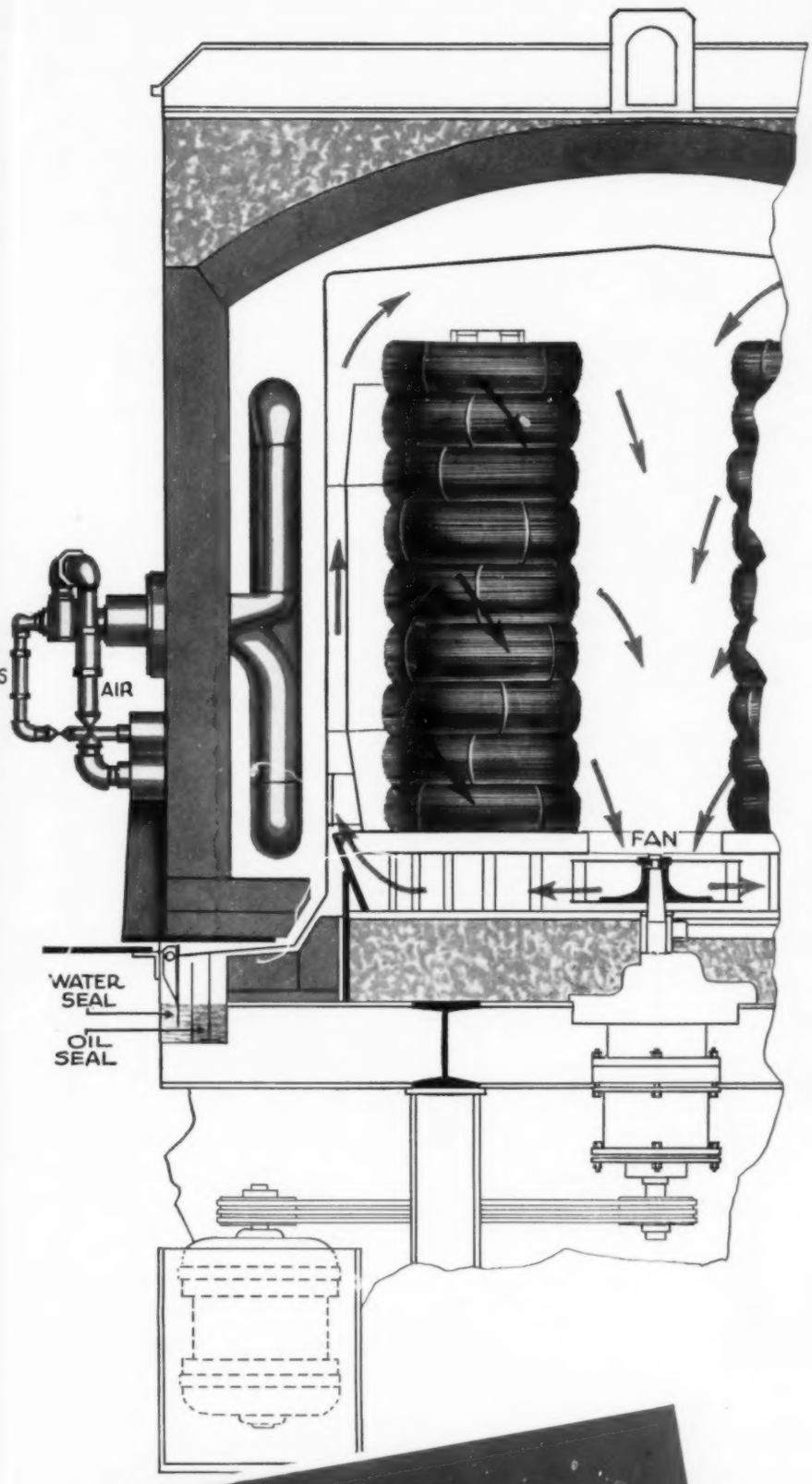
THE YOUNGSTOWN WELDING & ENGINEERING CO.
3703 OAKWOOD AVE. • • YOUNGSTOWN 9, OHIO

Lee Wilson announces the New

RADIANT CONVECTOR FURNACE

for

Wire Annealing



THIS NEW WIRE ANNEALING furnace utilizes the high speed convection heating system developed for and widely used in Wilson furnaces for strip coil annealing.

A high static, high volume fan, driven by a motor rated from 10 to 20 HP drives the gases through an annulus between the inner cover and inner cover liner at velocities which produce heat transfers resulting in faster heating, faster cooling and better physical properties in the material being annealed.

To provide the greater amount of heat input required for this faster processing, these furnaces are equipped with "O" type radiant firing tubes. Fuel economies of at least 15% result from the use of this new type of firing tube.

PATENT No. 2,485,995

Lee Wilson ENGINEERING Co., Inc.

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INDUSTRIAL FURNACES • RADIANT TUBE HEATING • HEAT TREATING PROCESS

ore, coal, scrap iron and steel, limestone, fuel oil and others. In establishing the new record, Weirton's 12 open hearth furnaces produced an average of 16,698 tons of ingots per furnace per month.

Weirton Steel Co., which is a subsidiary of National Steel Corp. is the world's largest independent producer of tin plate and a leading producer of a wide range of other steel products.

DETROIT STEEL BUYS PORTSMOUTH STEEL CORP.

▲ Detroit Steel Corp. has announced an agreement to acquire the physical assets and steel business of the Portsmouth Steel Corp. of Portsmouth, Ohio, on January 1, 1950.

The agreement calls for large-scale expansion of Portsmouth Steel's present finishing facilities.

The purchase price is to be based on book values on the purchase date, and will be payable partially in common stock of Detroit Steel and partially in cash. Meetings of the stockholders of the two companies will be held in the near future to ratify the agreement. Portsmouth Steel's properties include extensive steel producing facilities located on the Ohio River at Portsmouth, Ohio, and two coal mines in eastern Kentucky. The Portsmouth works include 108 by-product coke ovens, a blast furnace, and 10 open hearth furnaces with an annual ingot capacity of 720,000 tons, supplemented by a blooming mill, billet, rod and wire mills and equipment for the production of manufacturers' and merchant wire products.

Detroit Steel Corp. owns and operates cold rolled strip mills at Detroit, Mich., and New Haven, Conn., with a combined annual capacity of 210,000 tons. Its Reliance steel division processes and distributes flat rolled steel products including the product of its own mills with warehouses in Detroit, Cleveland, Chicago and New Haven. Its Craine-Schrage steel division operates a general steel warehouse in Detroit, specializing in cold drawn and hot rolled carbon and alloy steel bars, tool and die steel, and other products.

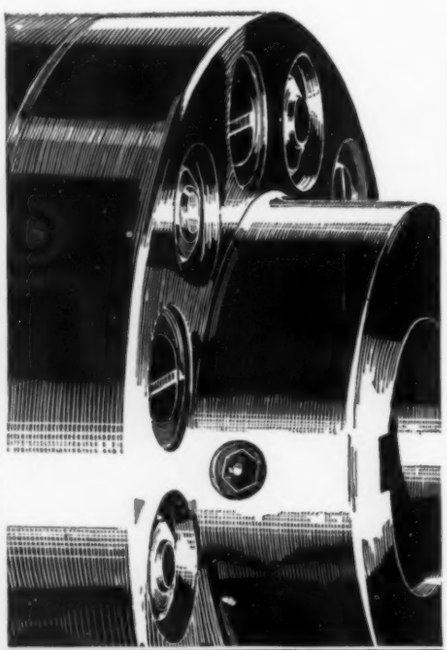
The facilities, management and personnel of Detroit Steel and Portsmouth Steel are to be consolidated into a single corporate unit, without interrupting the continuity of Portsmouth Steel's operations, the announcement said.

The Detroit-Portsmouth agreement contemplates expansion of finishing facilities at the Portsmouth works through installation of a hot rolled sheet and strip mill and an electric weld pipe mill. The new hot mill will produce hot bands for the cold rolled strip mill at Detroit and skelp for the new pipe mill at Portsmouth.

The new mills are scheduled for completion late in 1950. Together with the existing wire mill and wire fabricating equipment, they will use all of Portsmouth's present ingot capacity, the announcement said. Consolidation of the steel producing and distributing facilities of these two non-competing units will result in a well balanced and completely integrated steel operation, it added.

Portsmouth will continue as a separate corporation with substantial working capital, and will retain its minority stock interest in Detroit Steel Corp., and its present holdings in raw material companies.

SAY YOU READ IT IN THE IRON AND STEEL ENGINEER



Ajax design permits installation vertically or horizontally. No lubrication.

Remember that all the horsepower goes through the coupling... put it up to Ajax.

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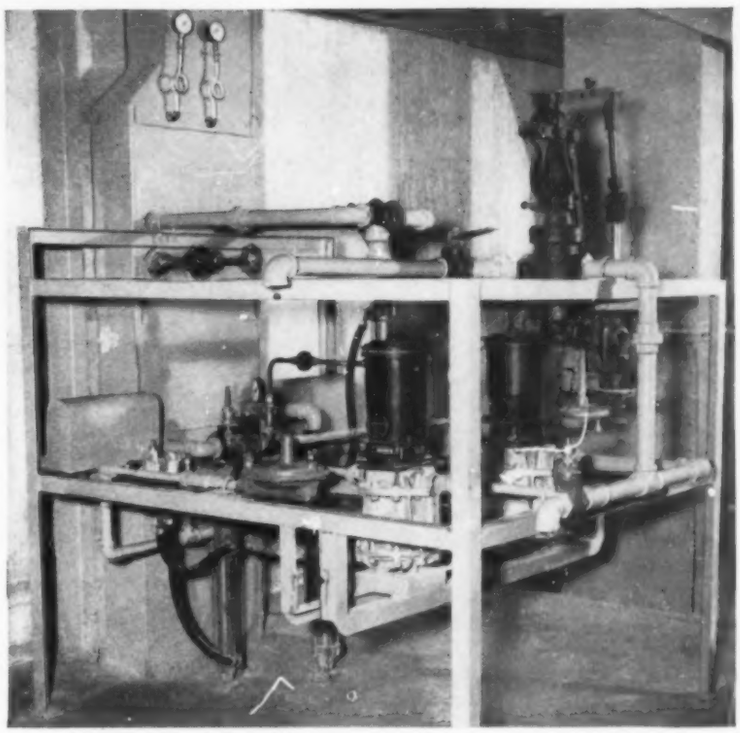
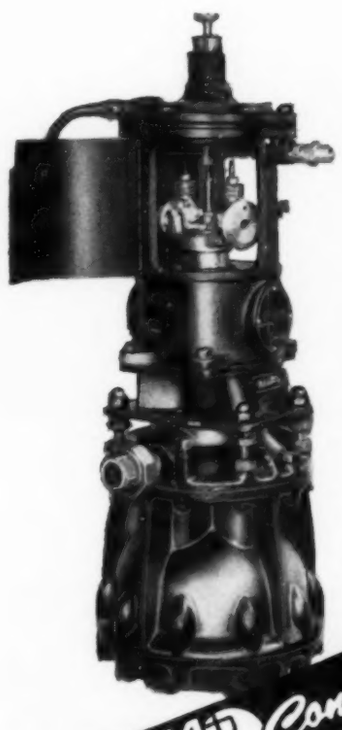


Here's How One Plant Did It . . .

In this case, at a feed mill, either molasses or concentrated fish solubles are mixed with various dry ingredients in the preparation of commercial cattle feeds. Gravimetric feeders were selected to deliver the *dry* ingredients at a predetermined, constant rate. But how to deliver the *liquids* at a continuous, predetermined rate was a problem. The Askania Transometer, designed for the accurate metering of liquids at an automatically controlled rate, was the practical, efficient answer. An Askania Unit Regulator is used to control operation of a control valve.



Wherever you have a need for accurately measuring and controlling the flow of liquids such as molasses, fuel oil, beer, gasoline, cottonseed oil, etc., you have a need for Askania Controls. The Askania Transometer (shown at left) accurately measures flow, regardless of changes in viscosity, pressure or temperature.

The metering system operates on the positive-displacement, piston-type method of measurement with the meter cylinders acting as measuring cups. Whether a fluid is used in just small amounts or full capacity none can pass through this metering system without being accurately measured.

The Askania Transometer is finding many applications in the steel, glass and process industries . . . for proportioning and mixing . . . for fuel-air combustion control and many others. Where can you use this efficient measuring system?

Send for Bulletin

Askania Bulletin No. 125 gives additional information on the operation and use of the Transometer. Send for your copy.

ASKANIA Controls

ASKANIA REGULATOR COMPANY

A SUBSIDIARY OF GENERAL PRECISION EQUIPMENT CORPORATION

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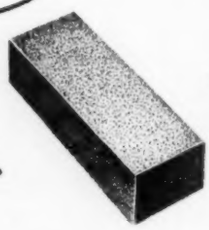
IT PAYS to keep a stock of "National" carbon brick on hand to be ready for any emergency...or to handle routine repairs smoothly and efficiently. You can now get "National" carbon brick in the new 13½" size, weighing only 14.4 pounds... *other sizes available for your particular requirements.* Carbon bricks are 20% to 45% lighter than the same sized ceramic bricks, yet do a better job in many ways. Here are some of the advantages of using "National" carbon bricks in blast-furnaces, runout-troughs, and other locations:



- **NO MELTING POINT OR SOFTENING POINT**
- **HIGH RESISTANCE TO SLAG ATTACK**
- **IMMUNE TO THERMAL SHOCK**
- **MORE ECONOMICAL TO USE**

For more information, write to National Carbon Company, Inc., Dept. IS.

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Foreign Department: New York, U. S. A.
These products sold in Canada by Canadian National Carbon Company, Ltd., Toronto 4.

Personnel News...

James W. Kirkpatrick has joined Youngstown Sheet and Tube Co. as chief metallurgist in the Youngstown, Ohio, district. Mr. Kirkpatrick is a native of Pittsburgh. After attending Pittsburgh public schools, he went to Carnegie Institute of Technology where he received a bachelor of science degree in metallurgy. At the age of 18, Mr. Kirkpatrick entered the steel business as an open hearth laborer at the Edgar Thomson works of Carnegie-Illinois Steel Corp., working there during successive summers. Following his graduation from Carnegie Tech. Mr. Kirkpatrick returned to Carnegie-Illinois and was employed in various capacities in the Kearney research laboratory, Homestead district works, and the Pittsburgh metallurgical division for eight years. He left there to join the H. A. Brassert Co. where he was assistant metallurgical engineer prior to joining Youngstown Sheet and Tube Co.

Eugene M. Smith of Columbus, Ohio, has joined Youngstown Sheet and Tube Co. as flat rolled products development engineer and will be located at the Campbell, Ohio, plant. He comes from Battelle Memorial Institute in Columbus where he was a research engineer. Mr. Smith is a native of Bethlehem, Pa. He attended elementary schools there, Liberty High in Bethlehem, Temple University in Philadelphia, Lehigh University, the University of Pittsburgh and Ohio State University. He has bachelor of science and his master's degrees.

For a period Mr. Smith was test foreman assistant for Bethlehem Steel Co., then went with the Aluminum Co. of America at New Kensington, Pa., as operating engineer before going to Battelle.

F. E. Kling has been named chief engineer, H. A. Brassert and Co., New York, N. Y. Mr. Kling went with Brassert as chief engineer, special products division and held that title until his recent promotion. He formerly was assistant chief engineer, Carnegie-Illinois Steel Corp., Pittsburgh, Pa.

Chester M. MacChesney was elected chairman of the board of Acme Steel Co., Chicago, Ill. This action was taken to fill the vacancy of chairman, caused by the death of Charles S. Traer. Mr. MacChesney became associated with Acme in 1916 as a design engineer, and later held positions as head of the engineering department and superintendent of the Archer Avenue plant. In 1923 he was elected to the board of directors and in 1948 he was elected executive vice president.

Ernest Holme has been promoted to superintendent of the Indiana Harbor rolling mills of Youngstown Sheet and Tube Co., Indiana Harbor, Ind., his second major promotion in a little more than six months. Early this year Mr. Holme, a roller, was appointed assistant superintendent of the mills, succeeding his brother, Kenneth, who was made superintendent of the company's tin mill hot strip mill at the Indiana Harbor works. In the second promotion, Ernest succeeds **J. M. Mitchell,** who left the company. Ernest Holme joined the company at the age of 18 as weighmaster at the 10-in. skelp mill, a unit of the rolling mills. He served on line jobs of charger and heater helper. In 1927 Ernest entered the bar mill and six years later was made a roller in the bar and billet mills, a position he held until his advancement early this year.

William A. Holt, following almost 16 years of service with Atlas Steels, Ltd., in Welland, Ontario, Canada, the latter eight years as assistant superintendent of maintenance and service department, has accepted the position of assistant manager, material control, Addison Industries, Toronto, Canada.

Comer D. Hazen is now with the Companhia Siderurgica Nacional, Volta Redonda Estado de Rio, Brazil, S. A. Mr. Hazen was formerly superintendent of maintenance, Wheeling Steel Corp., Benwood, W. Va.

G. Greer Coolidge, senior vice president of Harbison-Walker Refractories Co., was elected a director of Blaw-Knox Co., Pittsburgh, Pa. Mr. Coolidge has been associated with Harbison-Walker since 1907 and has been a director and vice president of this firm since 1933. Mr. Coolidge will fill the vacancy on the Blaw-Knox board occasioned by the death of the late Donald C. Bakewell.

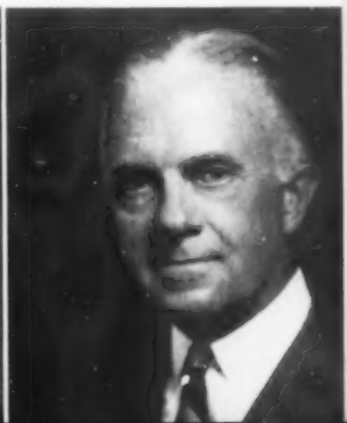
Seven executives of the General Electric Company's apparatus department have been named to new positions. The appointments are: **Neil Currie, Jr.,** from manager of manufacturing to administrative assistant

J. W. KIRKPATRICK

EUGENE M. SMITH

F. E. KLING

G. GREER COOLIDGE



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to the general manager. **Ernest E. Johnson,** from manager of engineering to manager of engineering, large apparatus divisions. **Carl A. Salmonsen,** from manager, aircraft gas turbine divisions, to manager of manufacturing, large apparatus divisions. **Byron A. Case,** from assistant to manager of engineering, to manager of engineering small apparatus divisions. **Frank T. Lewis,** from manager of manufacturing, aeronautic and ordnance systems divisions, to manager of manufacturing, small apparatus divisions. **Clarence H. Linder,** from assistant manager of manufacturing to assistant to the general manager.

T. E. Anderson was appointed district sales manager of the Chicago, Ill., office of Ohio Ferro-Alloys Corp. This fills the vacancy created by the death of **B. A. Patch, Jr.,** in October, 1949. Mr. Anderson has been handling the central district sales out of the main office at Canton, Ohio.

Christopher H. Williams was named vice president of Pittsburgh Engineering and Machine Co., in charge of engineering and sales.

F. P. Taugher was appointed manager of engineering for the Westinghouse Electric Corp.'s industrial control division, Buffalo, N. Y. Mr. Taugher has been engineering and service manager in the company's New England district for the past five years.

Fred Denig, vice president, has been made manager of the production department of Koppers Co., Inc. **Dr. G. Frank D'Alelio** has been named vice president and manager of the research department, the position formerly held by Mr. Denig. It was also announced that **Dr. A. R. Powell,** who has been assistant manager of the research department, has been made associate manager of that department.

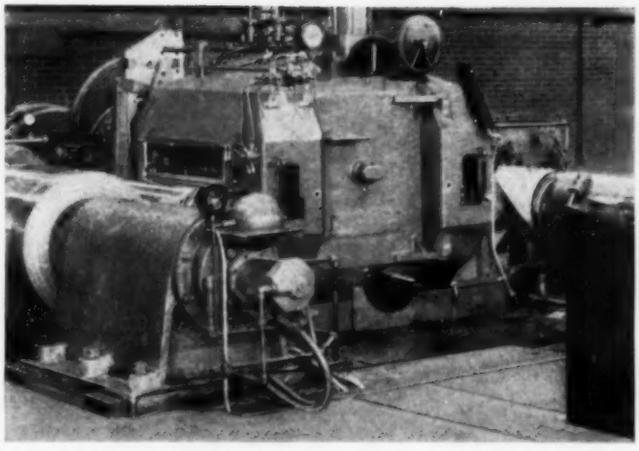
A. A. Johnson was recently appointed manager of central station engineering in the industry engineering department of the Westinghouse Electric Corp., East Pittsburgh, Pa. Mr. Johnson succeeds **Dr. Charles F. Wagner** who has recently been named consulting engineer for the company. In his new position, Mr. Johnson will coordinate engineering activities of the company on problems of generation, transmission, distribution, and system protection for electrical utilities and large industrial plants.

Hilding Carlson was appointed advertising and sales promotion manager of Selas Corp. of America, Philadelphia, Pa. Formerly managing editor of Dodge Reports Press Service, Mr. Carlson also has been regional executive of the United States Bureau of Labor Statistics in the Cleveland and New York regions. Most recently he was an associate in the firm of E. Holley Poe & Associates, natural gas consultants, New York, N. Y.

Fred G. Baker was appointed as director of engineering and design for Electro-Chemical Supply and Engineering Co., Emmaus, Pa. Mr. Baker is a chemical engineer graduate of the Iowa State College and until recently, a member of the engineering department of the E. I. du Pont de Nemours & Co., Inc., Wilmington, Del.

Whitney E. McDowell was appointed to the sales staff of Barney I. Florey Co., 3782 Ridge road, Cleveland, Ohio. The Florey Co. is Cleveland representative for the Automatic Transportation Co., Chicago, Ill., manufacturer of electric industrial trucks. Mr. McDowell, a native of Cleveland, is a graduate of the Case Institute of Technology. Before joining Florey

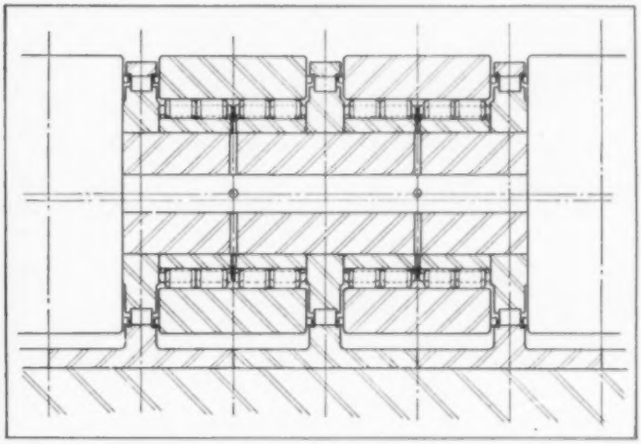
Torrington Bearings help Sendzimir mills roll steel to tissue thinness



The Sendzimir cold strip mill above, engineered by Armzen Company, rolls a super-accurate strip to tolerances of one to two ten-thousandths of an inch. Secret of its accuracy, as well as its ability to roll fine gages, is its use of small diameter work rolls with a radically new roll-backing principle.

The backing elements consist of these shafts carrying special Torrington Radial Roller Bearings alternating with saddles. Outer races of these bearings are in direct contact with either the work or intermediate rolls. The roll separating force is transmitted through intermediate rolls to these bearings.

To provide tremendous capacity, each bearing employs four rows of rollers, with a cage assuring positive roller guidance. The outer race has an exceptionally heavy section to prevent distortion and provide a rigid backing for intermediate rolls. Precision construction assures minimum wear and long service life.



This cross-section of the backing elements shows how roll separating forces, carried by the Torrington Roller Bearings, are transmitted through shaft and saddles to the housing. This construction and the high radial capacity of the bearings account for the exceptional rigidity and accuracy of the mill.

This is but one outstanding example of Torrington's ability to engineer anti-friction bearings to meet specific and exacting application requirements. Call on Torrington to solve your friction problems, routine or unusual. THE TORRINGTON COMPANY, South Bend 21, Ind., or Torrington, Conn. District offices and distributors in principal cities of United States and Canada.

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This double reduction De Laval Worm Gear Speed Reducer is available in many standard ratio combinations, with horizontal or vertical output shafts and is but one of 93 sizes and types of standard De Laval Worm Gear Speed Reducers.

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he worked for the American Steel & Wire Co., and then was a field engineer for the Edison Storage Battery division of Thomas A. Edison, Inc., in Cleveland.

Homer A. Goddard, Jr., has been named assistant general manager for industrial marketing for Gulf Oil Corp., Pittsburgh, Pa. In his new post, created as part of the firm's reorganized domestic marketing program, Mr. Goddard will be responsible for direct sales of Gulf products to industrial plants and organizations. A native of Wellston, Ohio, he received his education at Ohio University and at Colorado School of Mines, from

HOMER A. GODDARD, JR.

which he was graduated in 1925. Mr. Goddard worked for several years in the operating end of the brick and coal mining industries. He later served with Bethlehem Steel Corp. and with Mine Safety Appliances Co. in industrial sales. He joined Gulf in 1932 as industrial lubrication engineer with the Pittsburgh division, later becoming superintendent of industrial sales for the division, and then assistant division manager in charge of industrial sales.

Obituaries

Henry P. Everitt, 55, assistant supervisor of employment in the Youngstown district of Youngstown Sheet and Tube Co., died recently at his home in Struthers, Ohio.

Charles E. Brown, Jr., 55, vice president of Okonite Co., Passaic, N. J., died November 8, 1949, at St. Luke's Hospital, New York City, following a long illness. Mr. Brown was born in Buffalo, N. Y., and received his education at St. Mark's School, Southborough, Mass., and at Princeton University, class of 1917. During World War I he served overseas as an aviator in the United States Army. A former resident of Chicago, Mr. Brown started his business career with the Central Electric Co., Chicago, Ill. In 1925, he joined Okonite Co., as Chicago manager of their power and light department. In 1930 Mr. Brown moved to New York City to become assistant to the company's president, subsequently going to Washington, D. C., to establish a sales office. In 1941 he was appointed a vice president of Okonite, serving in that capacity as the company's Washington representative. After the war, Mr. Brown returned to New York, and in 1946, became vice president and general sales manager, which position he held at the time of his death.

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Lathes, Roll
Lathes, Slicing & Conditioning
Levelers, Plate
Machine, Flanging & Dishing
Manipulators, Mill, etc.
Mills, Blooming & Billet & Slabbing
Mills, Merchant & Bar
Mills, Plate
Mills, Rod
Mills, Sheet
Mills, Strip (Cold)
Mills, Strip (Hot) & Skelp
Mills, Vertical Edging
Mills, Ring
Planers, Plate
Pilers, Sheet & Plate
Pushers, Furnace
Repeaters
Rigs, Roll Changing
Saws
Shears, Alligator
Shears, Bloom, Billet, & Slab, Upcut, Downcut, Up-and-Downcut, Mechanical, & Hydraulic
Shears, Crop (Portable & Stationary)
Shears, Flying
Shears, Plate
Shears, Trimming and Slitting
Straighteners, Gag, Tables & Manipulators
Straighteners, Rotary
Stripping Machines, Ingot
Tables, Mill
Tables, Tilting & Lift
Tables, Transfer
Testing Machines, Pipe
Transfers

Tilting Table with Dragover and Separate Runout Table.

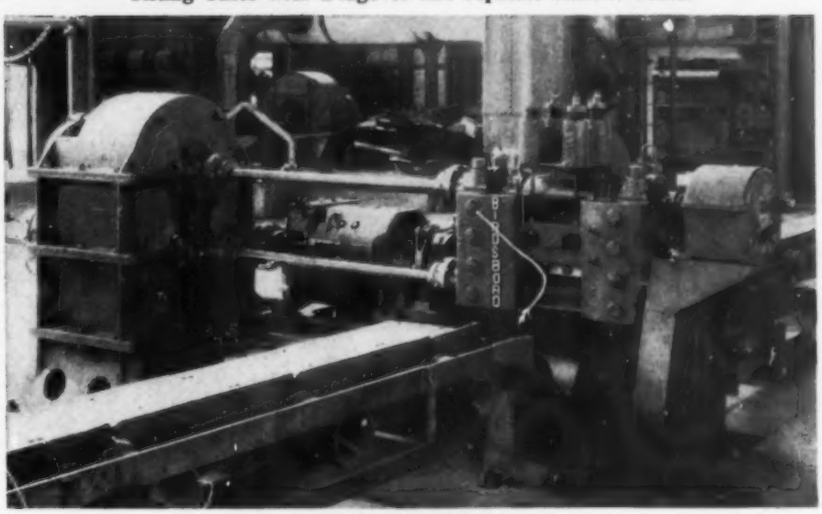

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Plate Mill Tilting Table with Mechanical Turnaround.

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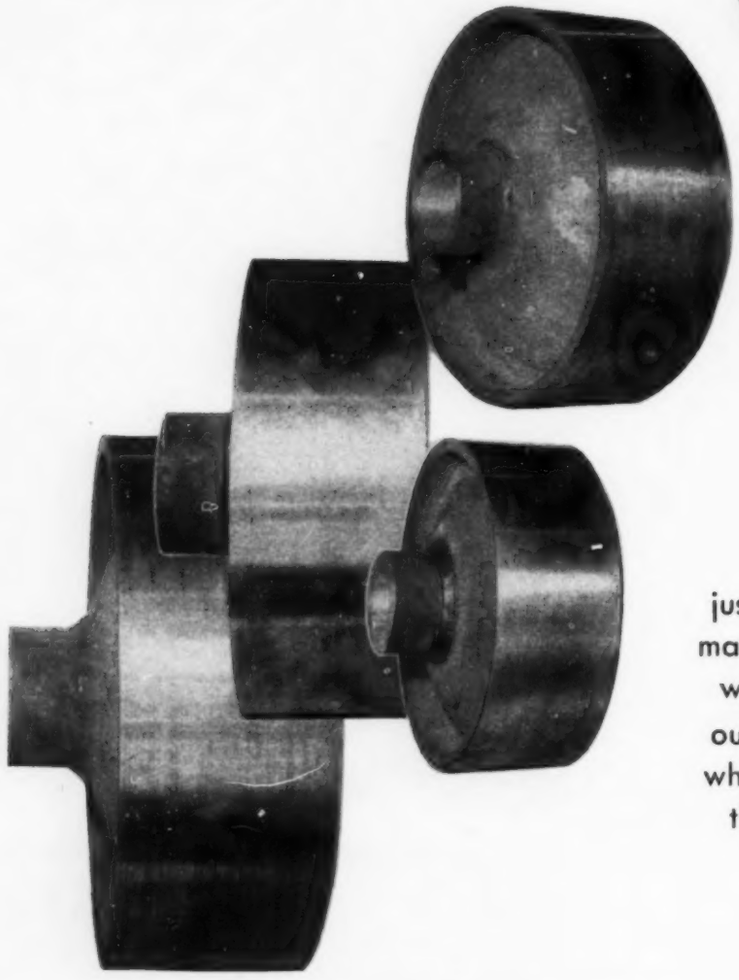

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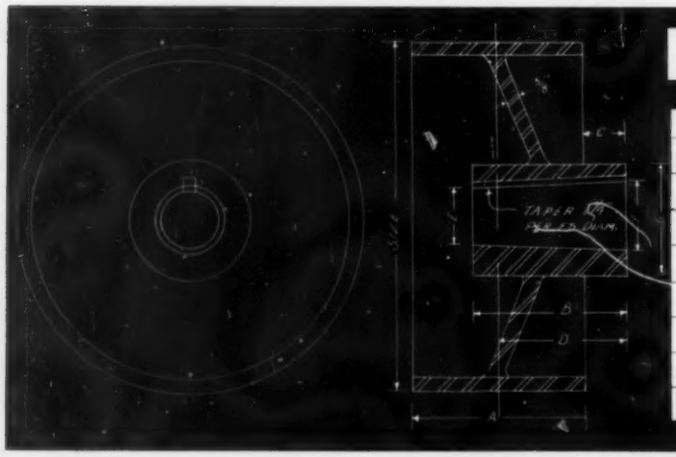

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30"	E	8½"	7"	½"	4¾"	3.870"	3.875"	5½"	⅞ x 7/"
24"	F	7½"	5"	½"	4¼"	3.495"	3.500"	5½"	⅞ x 7/"
21"	G	7½"	5"	½"	4¼"	3.620"	3.625"	5"	¾ x ¼"
18"	H	6¾"	4½"	3½"	6⅞"	3.245"	3.250"	5¼"	¾ x ¼"
21"	J	7½"	5"	3¾"	7½"	4.245"	4.250"	6"	1 x ⅜"
18"	K	3¼"	3½"	1⅞"	3½"	1.995"	2.000"	4"	¼ x ½"

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Bailey bulletin No. 17 shows how you can use this improved control system. Write for your copy and keep it handy for reference the next time you need process controls:

P-19

BAILEY METER CO.
1047 Ivanhoe Rd. • Cleveland 10, Ohio
BAILEY METER CO. LIMITED, MONTREAL
Controls for the Steel Industry
TEMPERATURE • FLOW • PRESSURE
GAS ANALYSIS • LEVEL • RATIO

4 + 8 Works Here at the Irvin Works of the Carnegie-Illinois Steel Corporation.

HERE'S A 40% CUT IN REFUSE DISPOSAL COSTS

Savings range from $20,000 to $200,000 per year

High labor costs, loss of operating time, haulage waste and expensive maintenance in your refuse disposal operation can be cut as much as 40%.

These great savings are realized through the use of big, tough Magor Automatic Air Dump Cars; cars designed specifically for steel plant service.

That's the answer – built specifically for steel plant service.

Today, a good many plants—large and small—use gondola, hopper or old type dump cars which were not designed to take the rough treatment unavoidable in refuse disposal operations. Therefore, maintenance, repair and labor costs have climbed tremendously—adding a staggering sum to the normal expenses incurred in such service.

A cost analysis survey made by Magor Engineers can determine the actual cost of your refuse disposal operations. They can show you, on the scene, how Magor Automatic Air Dump Cars can cut those costs.

Write today for complete information. There's no obligation, of course.

• A 30 yd. 70 ton Magor Heavy Duty Automatic Air Dump Car costs only $1.35 per day to own.

When writing, be sure to request your copy of the New Magor Air Dump Car Brochure. It shows how these modern steel plant cars can save you money.

MAGOR

CAR CORPORATION, 50 CHURCH ST., NEW YORK 7, N. Y.

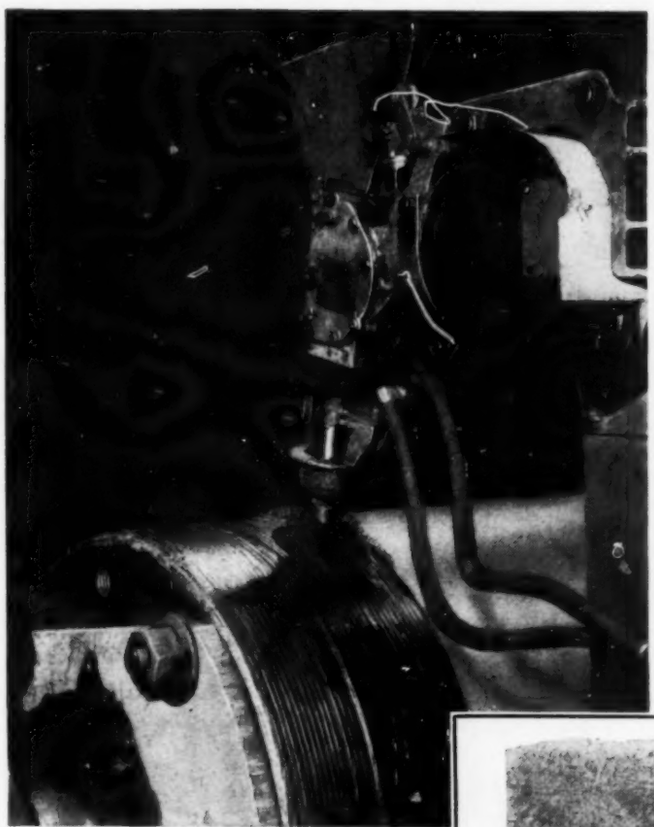
World's Largest Producer of Air Dump Cars

Give New Life to Worn Parts

. . . *Rebuild Them by UNIONMELT Welding*

This automatic process saves time and money—welding is fast—parts are returned to service quickly—new surface is often superior to original—

Almost any part that can be suitably positioned can be rebuilt by UNIONMELT welding. It has been used successfully on parts such as steel mill rolls, guides, mandrels, journals; wheels for locomotives, cars, and cranes; pipe molds, and press plungers and cylinders.



Rebuilding a 24 in. diameter press plunger.

Deposits of almost any thickness can be made of—

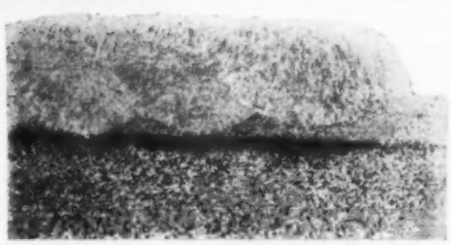
High carbon, flame-hardenable steels

Wear-resistant and hard-facing materials

Corrosion- and heat-resistant steels

With UNIONMELT electric welding, clean, dense, uniform weld metal can be deposited at the highest known welding speeds. There is no glare, flash, or spatter during welding. If a finished surface is needed, only minimum machining is required because of the smoothness of the weld deposit.

There are many LINDE methods of joining, rebuilding, forming, cutting and treating metals. LINDE Engineering Service can help you in production, construction, and maintenance. Just call the nearest LINDE office.



A flat surface is produced by offsetting each bead.

Linde
Trade-Mark

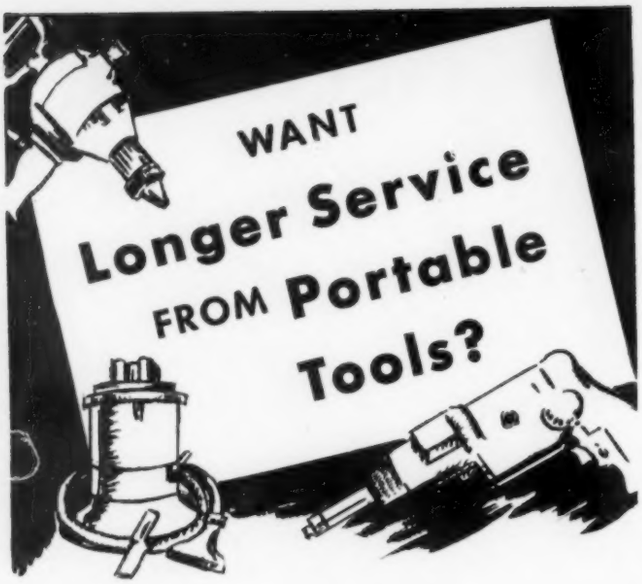
THE LINDE AIR PRODUCTS COMPANY

Unit of Union Carbide and Carbon Corporation

General Office: New York, N. Y. UCC Offices in Other Principal Cities

In Canada: DOMINION OXYGEN COMPANY, LIMITED, Toronto

The words "Linde," and "Unionmelt" are registered trade-marks of The Linde Air Products Company



Change to

NON-FLUID OIL

TRADE MARK REGISTERED

Most leading portable tool manufacturers use NON-FLUID OIL for the initial loading of their tools and recommend the continued use of NON-FLUID OIL to insure best performance.

Tests run by their designers and engineers have proved conclusively that special grades of NON-FLUID OIL give the most dependable, long-lasting lubrication of their portable tools—keeping down maintenance cost.

Write for free, testing sample of NON-FLUID OIL stating the make and model of the portable tool in which it will be used.

NEW YORK & NEW JERSEY LUBRICANT CO.

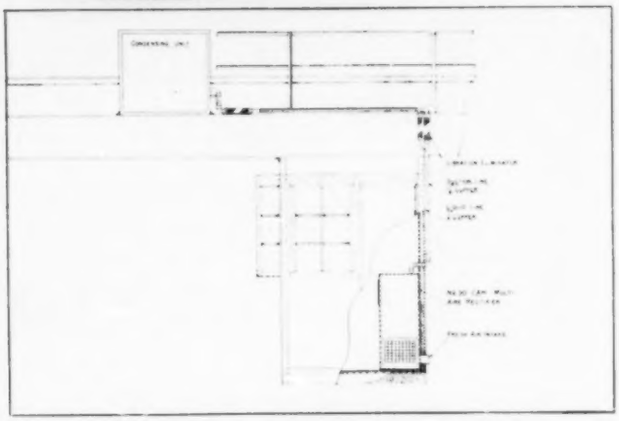
292 MADISON AVENUE, NEW YORK 17, NEW YORK

WORKS: Newark, N. J.

WAREHOUSES: Atlanta, Ga. • Greenville, S. C. Charlotte, N. C. • Providence, R. I. • Chicago, Ill. St. Louis, Mo. • Detroit, Mich.

NON-FLUID OIL is not the name of a general class of lubricants, but is a specific product of our own manufacture.

Sizes, Weights, Costs REDUCED in...



1950 MODELS

LINTERN Aire-Rectifier

The 1950 models of the "Little Giant" split system Aire-Rectifier now in production involve significant reductions in size and weight, yet with no sacrifice in capacity. Consequent savings in production are passed along to the buyers.

There are three new models in this series: 501AC-14 of 14,000 BTU capacity; 501AC-18 of 18,000 BTU capacity; and 501AC-27 of 27,000 BTU capacity. Typical of the saving in size and weight is 501AC-14. Its condenser unit measures only 46" long, 53" high, and 21" wide — weight, 1,225 lbs, as compared with the previous model, which measured 57" long, 49" high, and 23" wide — weight, 1,420 lbs.

All electrical equipment is protected and gives longer operating life.

The split system offers several definite advantages. (1) Reduced engineering costs. (2) Big savings by elimination of expensive, efficiency-reducing air ducts. (3) Higher cooling efficiency in the cab. (4) Greater flexibility in location of all equipment. (5) Lengthened life of operating equipment because of protection from excessive radiant heat and greater accessibility for service. (6) Location of Aire-Rectifier on existing cranes without moving any equipment. Savings run from $1,000 to $2,500 per installation.

Let us send you complete information.

THE LINTERN CORPORATION

54 LINCOLN AVENUE • BEREA, OHIO

You can't buy A LOWER COST-PER-YEAR VALVE than

HOMESTEAD-REISER *Self-Sealed* LUBRICATED PLUG VALVES

They are the lowest-priced, full-port-area plug valves in their pressure and temperature range

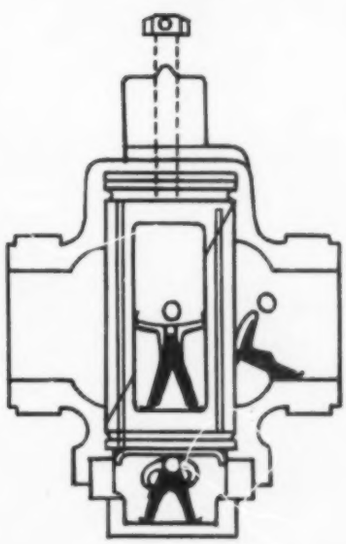
And they *outlast* all other lubricated plug valves in their class. Every one of their many outstanding advantages including

100% area of standard pipe
100% lubricant seal around ports
Extreme economy of lubricant
Single lubricant for wide variety of applications, and
Self-sealing automatic adjustment for wear

. . . are features asked for by engineers and operating men of industry.

Proof of their long, economical, dependable performance has been established in practically every industry during the past seven years. And at their new low price, they are more than ever your lowest cost-per-year fluid control.

Why not send today for your free copy of Valve Reference Book No. 39-5? *It shows sizes, types and pressure ratings for Homestead-Reiser Valves.*



How the "*Self-Sealed*" Principle Works

In addition to a full lubricant seal around the ports and around the top and bottom of the valve, the wedge-action of the plug under line pressure, constantly presses the finely-finished surfaces of the plug outward against the seating surfaces of the body. This self-sealing action keeps the plug surfaces in contact at all times with the mirror-like bore of the body. The plug thus automatically adjusts itself for wear, assuring extra long life and maximum leakless service.

Write today for Reference Book 39—Section 5

HOMESTEAD VALVE MANUFACTURING CO.

"Serving Since 1892" P. O. Box 21 Coraopolis, Pa.

LOOK TO THE FUSE LEADER FOR PRODUCTION PROGRESS

WARE HI-LAG Renewable FUSES

Only 3 PARTS

To Handle In Renewing Link

WARE HI-LAG FUSE Construction establishes a top standard for rugged simplicity. There are only 3 PARTS to handle to replace blown link: — the Fibre Case — the Knife-Blade Assembly — the Closure Ring. Only 1 wrench needed to loosen nuts and slip out blown link. Assembly can be inserted either end in Case.

WARE FUSE CORPORATION

4460 W. LAKE ST. CHICAGO 24, ILL.

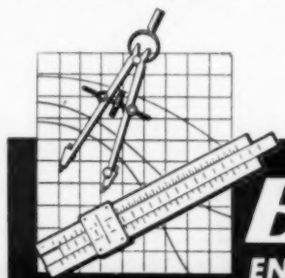
FOR FASTER HEATING
UNIFORM TEMPERATURES
GREATER FLEXIBILITY

THE BLOOM

TEMPERED FLAME BURNER

You get more from your furnace and more from your fuel with Bloom Tempered Flame Burners! Furnace temperatures from 400° F to 2450° F can be readily maintained. This burner eliminates cold spots and hot spots, thus reducing time of annealing cycles. It assures a uniform temperature throughout the furnace chamber.

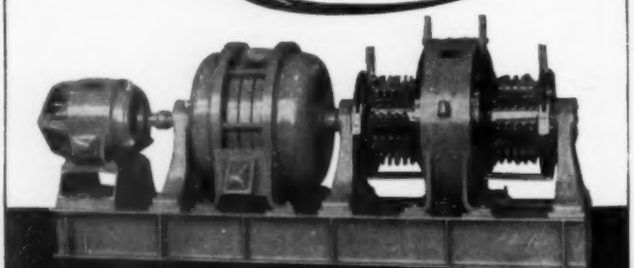
WRITE for complete details.



BLOOM ENGINEERING CO., INC.

857 W. North Avenue Pittsburgh 12, Pa.

Motor Generators by COLUMBIA



For
Electroplating — Anodizing
Electrocleaning — Electropolishing

There's a Columbia M-G Set available for your needs, whether you have a small plating bath or a large continuous strip plating line. Capacities up to 20,000 Amperes; 6 Volts and up. Dependable, performance proved, for many years. Your inquiries solicited.

Write today for Catalog IS-700

COLUMBIA ELECTRIC MFG. CO.

4543 HAMILTON AVENUE CLEVELAND 14, OHIO

BLAST FURNACE COPPER CASTINGS

Tuyeres - Tuyere Coolers
Cinder Notches - Notch Coolers
Bosh Plates - Mantle Plates
Hot Blast Valves and Valve Seats

Standard, Special and most Patented Designs to your specifications.

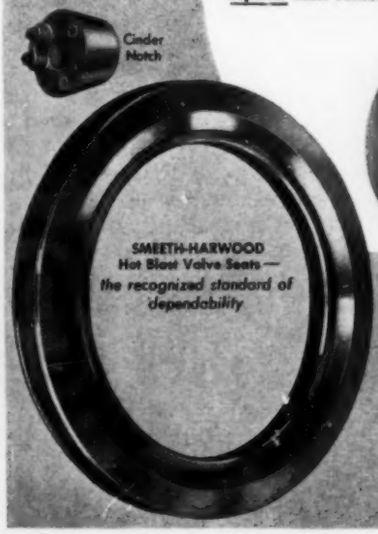
Heavy Nose, Super-Cooled Bosh Plates — for the Tuyere Zone where plates are most apt to burn.

SMEETH-HARWOOD COMPANY

2401-09 West Cermak Road, Chicago 8, Illinois

Superior Blast Furnace Copper Castings Exclusively

Cinder Notch



SMEETH-HARWOOD Hot Blast Valve Seats — *the recognized standard of dependability*

Refractory Lined Safety Coolers

Steudel Tuyere shaped to eliminate cutting underside of nose

OVER 30 YEARS EXPERIENCE
BUILT *into Steel Grid Resistors*
designed by POST-GLOVER

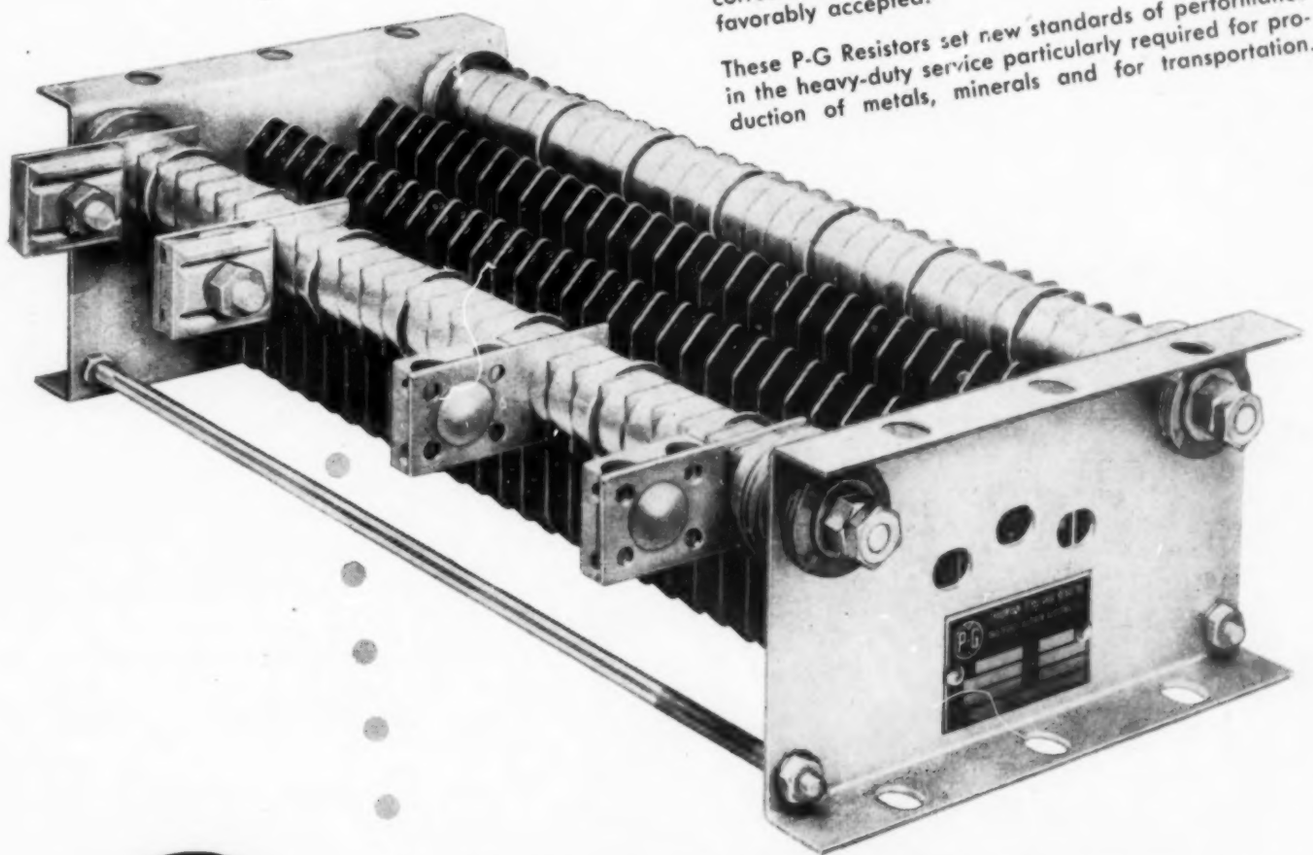
More than thirty years ago, to meet a demand for resistors capable of longer, trouble-free service, Post-Glover introduced a "Steel Grid Resistor."

These original "nonbreakable" resistors met instant favor, since they operated continuously under such adverse conditions as the dust, moisture and vibration of coal mining service.

From the experience thus accumulating through years of intimate association with actual heavy-duty operating conditions, the present P-G Type T2 Steel Grid Resistor was developed.

The all-steel construction, mica insulation, provision for expansion as well as resistance to moisture and corrosion of Type T2 continues more than ever to be favorably accepted.

These P-G Resistors set new standards of performance in the heavy-duty service particularly required for production of metals, minerals and for transportation.



SPECIFY P-G FOR YOUR NEXT APPLICATION

The Nonbreakable Steel Grid Resistor

THE POST-GLOVER ELECTRIC COMPANY

•ESTABLISHED 1892•

221 WEST THIRD STREET, CINCINNATI 2, OHIO

15-TON SCARFING BUILDING CRANE

BUILT BY MORGAN Engineering

Illustrated is a Morgan 15-ton, 3-motor, 40′-0″ Span Half Gantry Type Scarfing Building Crane. Hoist is actuated through a worm reduction unit for operating a counterweighted hoist rack connected to two lifting magnets, for handling slabs.

THE MORGAN ENGINEERING CO.

ALLIANCE, OHIO PITTSBURGH—1420 OLIVER BUILDING

DESIGNERS • MANUFACTURERS • CONTRACTORS • BLOOMING MILLS • PLATE MILLS • STRUCTURAL MILLS • ELECTRIC TRAVELING CRANES • CHARGING MACHINES • INGOT STRIPPING MACHINES • SOAKING PIT CRANES • ELECTRIC WELDED FABRICATION • LADLE CRANES • STEAM HAMMERS • STEAM HYDRAULIC FORGING PRESSES • SPECIAL MACHINERY FOR STEEL MILLS

Equipment News...

AUTOMATIC DEGASSER DESIGNED FOR USE IN DETERMINATION OF STEAM PURITY

▲ A new device, designed primarily for use in determination of steam purity, is anounced by Hagan Corp. Known as the Hagan automatic degasser, it produces continuously and automatically an approximately 50-50 split of a flowing steam sample—one fraction of the condensed steam containing any dissolved solids that may be present, and the other any dissolved gases.

In extensive field tests, involving use in a number of plants selected to provide a wide variety of conditions, the new degasser has given trouble-free automatic operation, it is reported. In all cases, carbon dioxide (CO_2) has been completely eliminated from the fraction containing dissolved solids, and ammonia (NH_3) has been eliminated, or reduced so greatly that it is no longer a factor in conductivity measurements.

The fraction of the condensed steam sample which contains dissolved solids free from gases is run through a cell in which its electrical conductivity is measured, thus providing an accurate indication of steam purity—accurate because the influence of gases on conductivity is effectively eliminated.

A principal advantage is the new degasser's automatic operation, it is pointed out. It does not require valve-twisting or frequent attention. Installation is easy and simple because the unit is compact and requires little in the way of connections. Its steam demand also is modest—about 30 lb per hour.

The flowing steam and condensate contact only stainless steel in this unit, it is further pointed out, so that contaminating materials are not picked up.

The time interval from entrance of steam into the degasser to passage of the degassed condensate out of the conductivity flow cell is small—approximately one minute. This means that the plant operator can readily correlate recorder charts made in conjunction with the degasser with steam flow, superheat temperature, or other operating charts to obtain a coherent over-all picture of conditions. This negligible lag, Hagan engineers explain, is due to the very low fluid holdup in the degasser, and to use of a flow cell with a small chamber.

A second cell is provided to measure the conductivity of the gas fraction. Both the solids fraction and the gas fraction can be diverted for chemical analysis.

VERSATILE FURNACE OFFERS HIGH CAPACITY

▲ To meet the demands of heat treaters for a versatile furnace which would offer high production capacity with a minimum of capital investment, Surface Combustion Corp. has developed a new batch-type radiant tube fired unit. This modern furnace is designed for clean hardening, gas carburizing, dry cyaniding and other controlled atmosphere heat treatments.

Many heat treaters have expressed their desire for a controlled atmosphere furnace which would be somewhere near the cost of a standard furnace and yet embody the high production characteristics of a specialized unit. These heat treaters also wanted a unit which would have much greater flexibility than that normally found in a high production special furnace.

After extensive engineering development and field test work, Surface Combustion Corp. announces its new high production batch-type furnace for all types of control atmosphere heat treatment of steel. The furnace is available with the built-in RX atmosphere generator to provide for gas carburizing, homogeneous carburizing, dry (gas) cyaniding and carbon restoration, clean hardening and general heat treating. Work is carried in and out of the furnace on four trays which are moved by alloy screws. A lowerator quench mechanism is included which provides "semi-automatic" operation for the charging and discharging of the furnace.

Extremely fast heating rates developed by the use of radiant tube firing, combined with a fan to circulate heated, prepared atmosphere, provide production up to 200 lb per hour gross loads per square foot of area. The furnace has a maximum gross charge capacity up to 2500 lb, depending upon the type of work to be processed.

Floor space requirements of this furnace are extremely low in view of production capacity. With the RX atmosphere generator built integrally into the furnace unit, a 16 ft long by 9 ft wide space is adequate for the entire furnace.

Operating reports to date indicate the unit's capacity for light case cyaniding at less than one-half cent per pound of work, exclusive of burden and fixed charges.

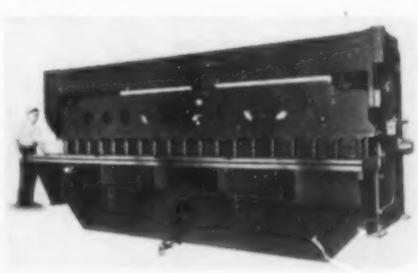
LONGEST SHEAR USES PIVOTED BLADE PRINCIPLE

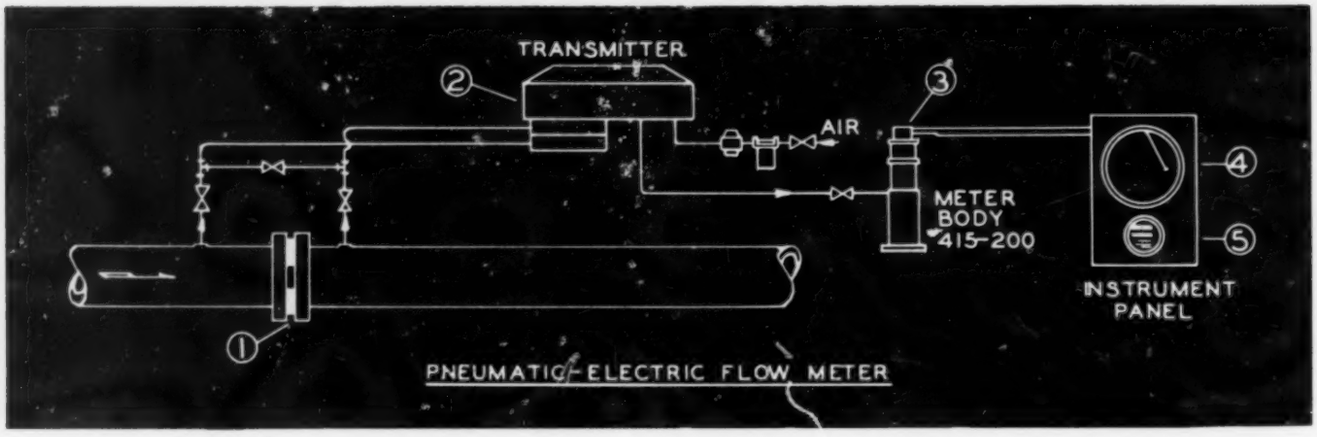
▲ The longest "Steelweld" shear built to date has just been completed by Cleveland Crane & Engineering Co.

The machine has a shearing capacity of 18 ft of $^3/_{16}$ in. mild steel at 50 strokes per minute. Like all Steelweld shears it operates on the pivoted-blade principle. The blade travels in a circular path without the use of customary guides and slides common with guillotine-type shears. Thus, difficulties from wear at these points are eliminated.

Ball bearing transfers are provided in the bed, facilitating movement of steel through the knives. A motor-

The shear has a capacity of 18 ft of $^3/_{16}$ in. mild steel at 50 strokes per minute.





The Answer to Your OXYGEN *Metering Problems!*

Here is an oxygen flow metering system that will accurately integrate the rapidly fluctuating flows encountered in steel mill operations.

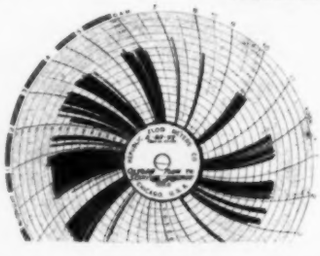
SENSITIVE METERING SYSTEM

The flow metering system, shown diagrammatically above, is a combination pneumatic-electric system for measuring a rapidly fluctuating flow of oxygen. It consists of:

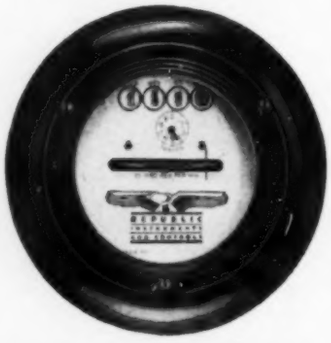
1. ACCURATE ORIFICE METERING
- No moving parts in the flow line.
- No stuffing boxes with grease to develop hazardous conditions.

2. PNEUMATIC TRANSMITTER
- Differential measurement of highest sensitivity.
- Oxygen confined by housing of suitable metals.
- No stuffing boxes.
- Stainless steel or Monel sylphon sealing bellows.

3. AIR ACTUATED ELECTRIC TRANSMITTER
- Converts air loading to electric current flow proportioned to oxygen flow.
- Suitable for electric transmission to distant instruments.
- No moving parts.



Flow of Oxygen to hot scarfing machine. Maximum flow 98,000 cu. ft. per hr. Duration of each flow 15 seconds.



Republic Continuous Integrator

4. OXYGEN FLOW RECORDER
- Equally graduated charts, direct-reading in flow.
- Permanent record of rates of flow.
- Record of time of changes in flow.
- Can be equipped with flow indicator.

5. CONTINUOUS INTEGRATOR
- Accurately follows all sudden changes of flow.
- Not the intermittent type taking spot readings.
- Completely independent of recorder.
- No clock involved.
- Cyclometer counter, plus dial for brief periods.

WIDE RANGE

For those installations where wide ranges of flow are encountered, a Republic pneumatic-electric metering system can be installed with a range of approximately 10 to 1. By a special piping arrangement, the range of accurate flow measurement can be extended to approximately 50 to 1.

The Republic pneumatic-electric flow metering system is completely described in Bulletin No. 48-2.

Write for your copy today.

REPUBLIC FLOW METERS CO.
2240 Diversey Parkway, Chicago 47, Illinois

operated back gage with slow and fast control buttons located conveniently at middle front of machine makes it easy to accurately position material to be cut. Because the back gage indicator is readily seen through the oblong slot in the hold-down beam, there is no need for the operator to walk to end or rear of shear to adjust the gage and many time-consuming steps are thereby saved. This indicator reads in inches and $\frac{1}{64}$ths.

The shearing action is controlled by an electrically-operated foot switch which can be moved about the floor to the convenience of the operator. The foot switch substitutes tireless toe action for tiresome knee action required by the conventional foot treadle which is ordinarily used to operate the clutch through mechanical means.

Frame and blade are of all-welded steel, one-piece construction with the heavy bed extending below the floor. The bed and crown are welded to the end housings, thus forming an integral unit having great strength. This construction assures minimum deflection and long-time accuracy.

The ease with which knife clearance is adjusted to suit thickness of plate being cut is an outstanding feature. It is simply a matter of turning a convenient handcrank and observing a large dial indicator. When the hand is on the figure corresponding to thickness of metal being cut, the machine is ready to go. The entire operation is handled in a matter of seconds. This assures maximum knife life.

Although this is the longest Steelweld shear, even longer and heavier ones can be supplied.

NEW DRUM PUMP USES ELECTRIC MOTOR

▲ Lincoln Engineering Co. announces a new "Centro-Matic" electric-motor operated drum pump (Model 1837) for use with original 55-gal barrels or 400-lb drums in conjunction with their centralized single line lubrication systems.

These full automatic time clock controlled drum pumps are designed for use with "Centro-Matic" lubrication systems where compressed air is not available, or where electrically powered and controlled equipment is preferred. Pumps include, as standard equipment, control panel with time clock adjustable for time-frequency settings, pressure switch, and signal alarm. Panel can be mounted adjacent to the pump, or in any location desired remote from the pump. A flanged steel drum cover, which fits over the top of center-opening or full open drums, provides sturdy mounting support for the pump, and protects lubricants from contamination. Motive power for the pump is furnished by a standard one hp motor. Pumps are gear driven, and include a built-in pressure relief valve for venting excess lubricant pressure from the lubricant supply line following discharge of the injectors in the system.

Motive power for the pump is furnished by a one hp motor.

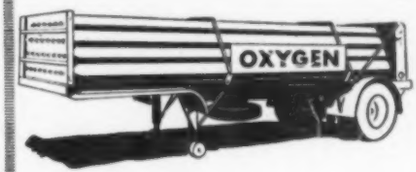
These powerful, heavy duty pumps are unexcelled for fast, positive delivery of heavy, viscous or fluid lubricants, and incorporate many exclusive and outstanding construction features which insure years of efficient, trouble-free performance.

TRANSFORMERS FOR SMOKE PRECIPITATORS

▲ Transformers for use as a source of high voltage in equipment for electrostatic precipitation of smoke, metals, or other materials from gaseous mixtures are available from Westinghouse Electric Corp. The new transformers are oil-insulated and hermetically sealed for long life and low maintenance. All major gaskets are eliminated by welding or soldering. Appearance is enhanced since the transformers have no projections or flanges. Lifting hooks have been recessed into the tank. Low-voltage bushings are in a well set into the top of the tank and hermetically sealed from the transformer itself. This well has a snap-on aluminum

(*Please turn to page 166*)

WHO PAYS THE FREIGHT?



when you buy

BY THE CUBIC FOOT

OXYGEN

BY THE TON

The handling of oxygen is a large part of the cost to most oxygen users — and you can ELIMINATE HANDLING COSTS FOR OXYGEN.

With Air Products generators, you take oxygen from the air and push it right through your pipe lines. You assure your supply at low cost, because with these generators there is

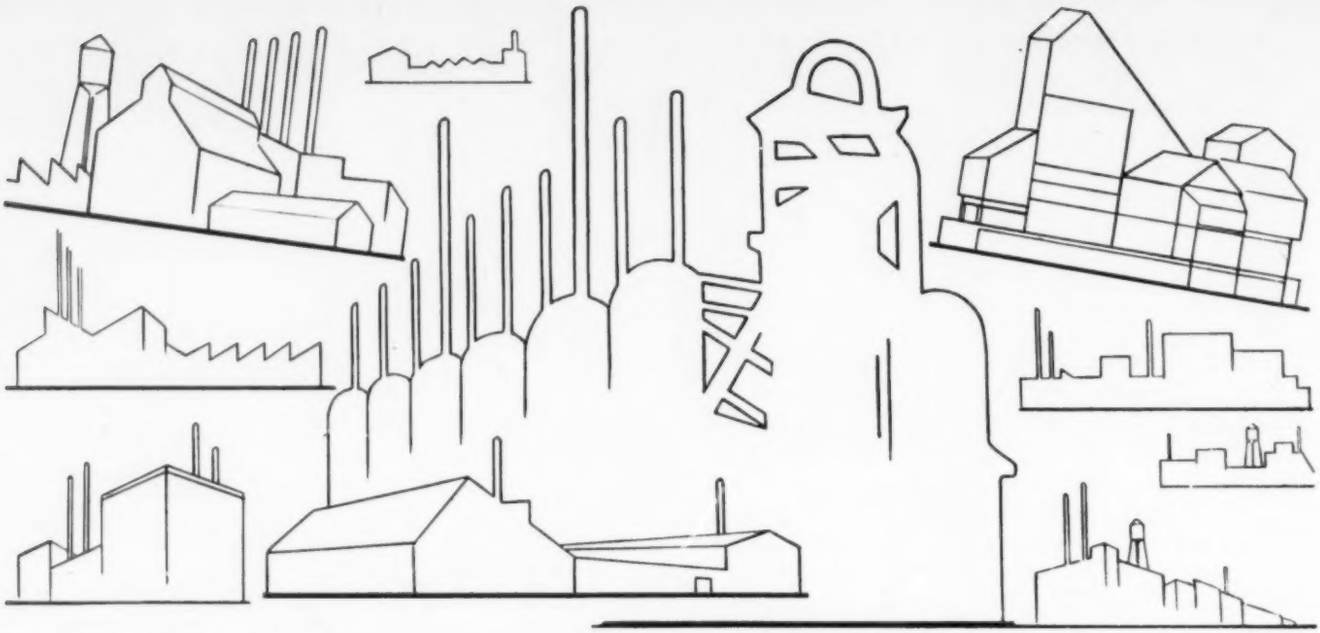
NO FREIGHT COST
NO HANDLING
NO EVAPORATION LOSS
NO RESIDUAL LOSS
NO DELIVERY FAILURE

If you use over 200,000 cubic feet of oxygen per month, it will pay you to get full information about Air Products generators and our lease plan. Write today, at no obligation.

AIR PRODUCTS, INC.
P. O. Box 538
Allentown, Pa.

Assure Your Supply at low cost with

Air Products
OXYGEN GENERATORS



ONE BUILDING OR A HUGE PLANT

your industry has "water problems"

If any phase of your pipe line operation is below peak performance, it is costing you money to operate. Let the engineering department of the Pittsburgh Pipe Cleaner Company explain a complete planned rehabilitation program for you.

Pittsburgh Pipe Cleaner Company's many years of experience and development in the Industrial Water Supply and Disposal Field gives them the ability to offer you a complete service in a planned rehabilitation program for your plant.

With the costs of maintenance, labor, and new equipment soaring to unprecedented heights, engineering analyses of water mains are the logical starting points in determining not only the condition of the system, but how it can most economically be made to serve a plant at minimum cost.

An Engineering Survey will reveal the adequacy of the system and our engineers are trained to make this survey for you, and to recommend the services needed.

WRITE TODAY.

- **Surveys**
  Water and Sewage Systems
- **Hydraulic Analysis**
  Water Systems
- **Analysis and Investigation**
  Sewer Systems
- **Pipe Cleaning**
  Water Mains — Sewers — Allied construction
- **Industrial Waste Control**

PITTSBURGH PIPE CLEANER COMPANY

133 Dahlem St., Pittsburgh 6, Pa.

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DECEMBER, 1949

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(1) Combustibles Recorder

Design improvements and new applications for the Bailey combustibles recorder are featured in a new 16-page bulletin now being distributed. Drawings and photographs explain the operation of this electronic type instrument which operates on the catalytic combustion principle. Typical applications to boiler furnaces, atmosphere producers, rotary kilns, industrial furnaces, and chemical processes are illustrated. Either air or electrically-operated control of combustibles content may be had with the combustibles recorder. Both are shown and explained. Also described, is the recorder's highly accurate a-c measuring circuit. (150-A). Bailey Meter Co.

(2) Cable Size Selection

"Selection of Proper Cable Sizes" is the title of a new booklet just issued by General Electric's Construction Materials Advertising Department. This publication deals with the method of determining cables and cable sizes of asbestos-varnished cambric cables, Types AVA, AVB, and AVL. Step-by-step instruction is given on figuring load current, voltage drop, cables, and cable sizes for both lighting and motor loads. Handy reference tables simplify these computations. (19-269). General Electric Co.

(3) Sling Chain Selection and Use

Recently issued is a wall chart that simplifies the selection of sling chain for every requirement and provides a permanent record of performance for specific chains used in shops and factories. Complete data on alloy and iron chains and the working load limits of sling chains in $\frac{9}{32}$ in. to 1 in. sizes are shown, as are the weights of the loads that can be lifted when a given sling is used at angles of lift from 10 degrees to 90 degrees. Standard single-leg, two-leg, three-leg and four-leg chains are illustrated with various attachments. The back of the chart lists the Chain Institute, Inc. definitions, instructions and cautions governing the use of sling chains. In addition there is a table for recording sling chain performance. Space is provided for identifying the chain, date of purchase, inspection, number of branches, etc. The chart is designed to be hung in the shop to become a permanent record of information on sling chain use and care. The chart and a sling chain data sheet are available. McKay Co.

(4) Magnetic Separator Catalog

A new 8-page illustrated bulletin, "Dings Certified Magnetic Equipment," has been released. The bulletin describes electric and non-electric magnetic pulleys, non-electric magnetic drums, triple pole rectangular magnets, lifting magnets, non-electric plate magnets, high intensity induced roll and cross belt magnetic separators and several other types of equipment. Data includes brief specifications, lists of applications and features of the equipment which is designed for separation of magnetic and non-magnetic products. Typical uses include removal of tramp iron to protect crushers, grinders and other machinery, purification of magnetic minerals from non-magnetic minerals. (C-5000A). Dings Magnetic Separator Co.

(5) Multi-stage Turbines

A new multi-stage turbine catalog is available. Material contained in the catalog includes a discussion of the economics of by-product power, along with diagrammatic sketches that show the utilization of heat for various typical plant operating conditions. The catalog points out the flexibility of turbine drive; it shows the basic types of De Laval turbines for different operating conditions and applications up to 20,000 hp. Several pages of photographs are devoted to design features of these turbines and a series of cutaway diagrams show various governing and control systems. Also included is a two-page spread on helical gears for applications where geared turbine driven equipment is used. (4200). De Laval Steam Turbine Co.

(6) Deaerating Heaters

A new bulletin on deaerating heaters has been published. The bulletin outlines the principles of deaeration, fully describes the design, operation and applications of Graver deaerating heaters, and explains their distinctive features. Both vertical and horizontal types of heaters are shown, and the illustrations also include flow sheets of this type of apparatus in conjunction with other feedwater equipment in intermediate pressure, high pressure and central station boiler plants. Graver Water Conditioning Co.

(7) Optical Pyrometer

Described in a new bulletin are two special lens assemblies which are being increasingly used with the standard L&N optical pyrometer for measuring molten steel temperatures during tapping, teeming, and spoon tests, or in the laboratory to make specialized temperature measurements. This publication shows how these special lenses, which provide a larger-than-usual image, are helping operators to make easier, faster temperature readings of thin or small-area objects. In addition, the catalog shows the easy interchangeability of these special lenses with the standard one used for all usual measurements. A typical application mentioned is the use of one of these lenses to sight at the darker, center streak of the tapping stream, and at the narrow ribbon of molten metal poured from the ladle during teeming, or from the spoon during spoon tests. The catalog also tells how laboratory personnel are using

the second lens to simplify temperature measurements of filaments and other hot objects $\frac{1}{32}$ in. in diameter or less (N-33D). Leeds and Northrup Co.

(8) Refractory Specialties

A catalog is available which gives complete description of refractory specialties available for furnace construction. The various items referred to in this catalog have been successfully used on soaking pit covers, furnace roofs and side walls, burner ports, forging furnaces, annealing ovens and normalizing furnaces. This catalog has considerable information and data that would be of use to any person concerned with boiler and furnace refractory materials. Ramtite Co.

(9) Commutator Handbook

A 44-page handbook of procedures and methods of commutator and slip ring maintenance is available to you. The maintenance and procedures described in this handbook have been proved over a period of many years in hundreds of operations. They represent what is believed to be the most practical approach to commutator and slip ring maintenance problems. The book is divided into four sections as follows: Trouble and How to Correct It; Brushes; General Maintenance Procedure; and Maintenance Products. An appendix of the various terms used in this type of maintenance is included in the end of the book. Ideal Industries, Inc.

(10) Carbon Mold Plugs

A new catalog section describes and illustrates the carbon mold plug and outlines the advantages of its use. "National" carbon mold plugs are manufactured in thirteen standard sizes, shown conveniently in a table. The stock sizes are available for immediate shipment while other standard sizes can be supplied on order in quantities of 1000 or over. Special arrangements can be made to supply standard carbon mold plugs for experimental purposes in quantities up to fifty plugs. A special report of one large mill listing the advantages experienced through the use of 45,000 carbon mold plugs in regular production is also available as a reprint. (M-8706). National Carbon Co., Inc.

(11) Rust Preventatives

Just published is a new booklet on rust preventatives. Entitled "A New All-Star Line-Up of Rust Preventatives," this 8-page booklet thoroughly describes and lists the many uses for each of the eleven "Rust Veto" products developed by Houghton and proved through years of use in industrial applications. A full page chart outlines the physical properties of each product and also lists such information as thickness and type of film, amount of coverage obtained in use and other pertinent data. Photographic evidence is shown of pieces subjected to severe testing. Various types of testing equipment are also illustrated. E. F. Houghton & Co.

(12) Carbon Run-Out Trough Liners

A new catalog section has been issued describing the use of carbon blocks for lining run-out troughs of blast furnaces. The standard carbon block shapes for run-out trough linings are recommended for installation from the tap hole to the splash plate. For lining the iron basin and runners, "National" standard carbon brick shapes should be used. The bulletin outlines design, installation, operation and ordering information, with pictorial and sectional illustrations. (M-8705). National Carbon Co., Inc.

(13) Share Cutting

Just published is a descriptive booklet on a new low-priced, portable, shape-cutting machine, the Airco No. 3 Monograph. The booklet covers in considerable detail the various features of this unique oxyacetylene shape-cutting machine. Four pages are devoted to "case-histories" of actual production work done by the machine in field trial situations. An additional four pages are devoted to operating characteristics and design features of the machine. (ADC660). Air Reduction Sales Co.

(14) Heat Processing Machines

Radiant gas heating rates of from one to five minutes per thickness inch ot steel and the consequent metallurgical advantages of faster metal flow and reduced scale formation are discussed in "Heat Processing Machines for Forging and Bending," a bulletin just issued. Longer die life, product uniformity, operator comfort, labor and fuel economies are included among the subjects of interest to forging and bending shop operators. Fully illustrated by photographs, charts and diagram, the bulletin points to faster production rates and reductions in costs as resulting from the use of automatic heating machines. (S-6.1). Selas Corp. of America.

(15) Generator Guide

"Your Guide to Profitable Installations of Modern Generators," a new 8-page bulletin tells in nontechnical language the points to look for when ordering generators. Exclusive construction features and what these mean in terms of continuous, economical operation are pointed out and illustrated. Many recent installations of large slow-speed engine-type generators are shown. (PRD-196). Electric Machinery Mfg. Co.

(16) Complete Electrical Catalog

A general catalog is available covering switches, circuit breakers, service equipment, motor control equipment, magnetic motor control, lighting and distribution panel boards, and general application data. The catalog, containing 176 pages, should be in the hands of every person using electrical equipment. It gives part numbers as well as list prices of various items. Trumbull Electric Manufacturing Co.

(17) Slide-Chart

Air Reduction, manufacturers of industrial gases and welding equipment, have announced that their oxyacetylene machine gas cutting slide-chart, introduced in 1946, has been reprinted and is now available upon request. The chart covers two of the most widely-used cutting tips, the Style 124 and the high-speed Airco 45. The tips are available in 18 different sizes, and all are included in the chart. By sliding the chart to the indicated tip number, oxygen and acetylene pressures, speed in in. per minute, gas consumption and approximate width of kerf are all easily read down one column. Cleaning drill sizes are also indicated. The chart is a pocket-sized 2¾ in. x 7 in. and can be comfortably carried in shop coat or overalls. Made of sturdy, 6-ply Tough-

check, it is reinforced with four metal eyelets and coated with a special long-wearing varnish. (ADI967). Air Reduction Sales Co.

(18) Gas-Fume Respirator

This illustrative bulletin covers the new MSA Gas-Fume Respirator for protection against mists, dusts, fumes, organic vapors and acid gases which occur in burning, spraying, pouring, welding, cutting and other industrial operations. Designed to combine protection with working comfort, the MSA Gas-Fume Respirator employs twin replaceable filters which are mounted on the wearer's back. Back-mounting removes the filters from areas of heavy contaminant concentrations, and also permits unobstructed vision and complete working freedom. Other comfort and safety features are the "Comfo" sure-seal facepiece, guarded exhalation valve, and inhalation check valve. The entire unit weighs only 2 lb 14 oz and is equipped with comfortable all-rubber headbands and neckbands for well-balanced fit. MSA Bulletin No. CR-23, 2pp. Mine Safety Appliances Co.

(19) Switching Locomotive

A new, 16-page bulletin, on the 80-ton diesel-electric locomotive for industrial switching describes the locomotive completely and shows why it is economical to operate. Fully illustrated, the bulletin points out salient features of the unit. General Electric Co., Bulletin GEA-3810A, "80-Ton Diesel-electric for Industrial Switching."

(20) Rotary Dryers, Kilns, Coolers

Just released is a 32-page catalog on a complete line of "Ruggles-Coles" rotary dryers, kilns, and coolers. The bulletin discusses direct, semi-direct and indirect heat dryers, double-shell and single-shell dryers, parallel-flow and counter-flow dryers, steam tube and hot air dryers. It covers air type, water spray, and partially submerged type rotary coolers; counter-flow rotary kilns for calcining, roasting or oxidizing. Included are overall dimensions of all models as well as typical "flow sheets" showing how the various rotary units are used in continuous flow operations in the mining, chemical, ceramic, stone products, coal, metallurgical, sewage treatment and other processes. (16-D). Hardings Co., Inc.

(21) Heliwelding

Covered in a 16-page descriptive booklet is heliwelding, an inert-gas, shielded-arc welding process. The booklet, 16 pp, is illustrated with more than 25 photographs, sketches and tables, and explains the process and when to use it, with such section headings as "Heliwelding Joins the Hard-to-Weld Metals" and "How Current and Polarity Affect the Weld." The booklet also contains sections on equipment for manual, semi-automatic and automatic operation; a new automatic filler-wire feeder, and power supply equipment. Air Reduction Sales Co.

(22) Deaeration in Feedwater Chemistry

A revision of the publication entitled "Cochrane Deaerators" has been announced by Cochrane Corp. The revised catalog combines the latest information on the importance of deaeration to feedwater chemistry, with a complete description of modern deaerating equipment manufactured by Cochrane. The 35-page publication includes a comprehensive study of the deaeration principle, profusely illustrated with diagrams and photographs of Cochrane Deaerators in use in widely varied types of service, together with an informative article titled "The Role of Alkalinity in Preventing Corrosion." Technical data on the operation of the various types of deaerating equipment is also given in the publication. Publication 3005. Cochrane Corp.

(23) New Data Book on Ball and Roller Bearings

An entirely new 112-page detailed catalog and engineering data book covering the Link-Belt complete line of ball and roller bearings, Book No. 2550 is now available. The new book points out the important construction features and gives list prices, weights, load ratings and all necessary dimensions for the various standard models available. The selection of the right bearing for the specific service has been greatly simplified, and a wealth of engineering information is given, including pages of selection examples and drawings of typical applications. A page on the inter-changeability of Series "DE" roller bearings with bearings of other makes should be found particularly valuable when selecting bearings for replacement installations. Other pages are devoted to welded steel base plates, lubrication fitting data, maintenance and lubrication, shafting, Link-Belt quality-controlled bearing manufacturing facilities; and there are five pages of photographs of a great variety of bearing installations. Link-Belt Co.

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PUBLICATIONS CURRENTLY OFFERED by Iron and Steel Engineer Advertisers

ITEM	COMPANY	BULLETIN	DESCRIPTION
50	AIR REDUCTION SALES CO.	CATALOG 8	A handy, useful new arc welding machine catalog.
51	ALLIS-CHALMERS MANUFACTURING CO.	BULLETIN 05B7150	Bulletin describes the new tube-type totally-enclosed fan-cooled motor.
52	ASKANIA REGULATOR CO.	BULLETIN 125	Bulletin gives additional information on the operation and use of the Askania Transometer.
53	BAILEY METER CO.	BULLETIN 17	Bulletin shows how four basic circuits and 8 basic component parts give you more than 100,000 different electronic instrument combinations for processing use.
54	BEDFORD FOUNDRY AND MACHINE CO.		Catalog available describing Befdord cranes with capacities from 5 to 150 tons.
55	BROWNING AND CO., INC., VICTOR R.	BULLETIN "S"	Bulletin on Browning mill type cranes, which are built in accordance with AISE specifications.
56	BUFFALO FORGE CO.	BULLETIN 2424-E	Contains all the facts on Buffalo exhausters.
			"Fan Engineering", a handy, pocket size reference on practically every phase of air and air handling.
57	CLEVELAND WORM AND GEAR CO.	CATALOG 300	Full description on Speedaire, Cleveland's new fan-cooled worm-gear speed reducer.
58	COLUMBIA ELECTRIC MANUFACTURING CO.	CATALOG IS-700	Catalog gives full details on Columbia motor generators.
59	CROCKER-WHEELER ELECTRIC MANUFACTURING COMPANY, DIVISION OF ELLIOTT CO.	BULLETIN SL-620-1	Complete details on why the Crocker-Wheeler Form W 600 series is your best buy in mill motors.
60	CROUSE-HINDS CO.		Condulet catalog available giving the complete listings of Crouse-Hinds plugs and receptacles available.
61	CUTLER-HAMMER, INC.	BULLETIN 14017	Bulletin gives complete description of d-c reversing dynamic braking control.
62	DE LAVAL STEAM TURBINE CO.	CATALOG 50-14-R	Catalog on De Laval double reduction worm gears.
63	DURABLA MANUFACTURING CO.	BULLETIN 9S8	Information available on the Durabla Valve Member, "The Valve That Grinds Itself."
64	EICHLEAY CORP.		New illustrated booklet available showing all types of erection, installations, etc.
65	ELECTRIC STORAGE BATTERY CO.		"Exide-Ironclad Topics," a bulletin which contains latest developments in materials handling and shows actual case histories.
66	FARREL-BIRMINGHAM CO., INC.	BULLETIN 115	Bulletin shows why the Farrel HD roll grinder is able to prove the unique "five-point performance."
67	GENERAL ELECTRIC CO.	BULLETIN GEA-4469	Describes the G-E motors, which are available in ratings from 15 to 200 hp.
68	HAGAN CORP.	BULLETIN 2M48	Bulletin gives full details on the Hagan ring balance flow meter.
69	HOMESTEAD VALVE MANUFACTURING CO.	REFERENCE BOOK 39—SECTION 5	Book shows sizes, types and pressure ratings for Homestead-Reiser valves.
70	LEEDS AND NORTHRUP CO.		Folder tells how integrated control helps mills get well-heated steel.
71	LINK-BELT CO.	CATALOG 2550	112 pages of descriptive and engineering data on the complete line of mounted and unmounted Link-Belt ball and roller bearings.
72	MAGOR CAR CORP.		A new Magor air dump car brochure shows how modern steel plant cars can save you money.
73	MORGAN CONSTRUCTION CO.		Bulletin explains the many advantages of the Morgan-Isley System over natural draft.
74	OKONITE CO.	BULLETIN IS-101	Bulletin contains complete details on the Okonite cable.
75	PENNSYLVANIA TRANSFORMER CO.	BULLETIN 1492	Gives full information on Pennsylvania standard parts power transformers.
76	POOLE FOUNDRY AND MACHINE CO.		Catalog gives full description and engineering data on flexible couplings.
77	REPUBLIC FLOW METERS CO.	BULLETIN 48-2	Bulletin completely describes the Republic pneumatic-electric flow metering system.
78	SQUARE D CO.	BULLETIN 7950	Bulletin on heavy duty d-c control for cranes and mill auxiliaries.
79	TIDE WATER ASSOCIATED OIL CO.		"Tide Water Associated Lubricania" gives clear, concise descriptions of the basic tests used to determine important properties of oils and greases.
80	WAGNER ELECTRIC CORP.	BULLETINS TU-13 AND TU-56	Describe the design and construction features that make Wagner liquid-filled and dry-type unit substation transformers outstanding.
81	YOUNGSTOWN WELDING AND ENGINEERING CO.		Descriptive literature available on the Weldco mechanical pickler.

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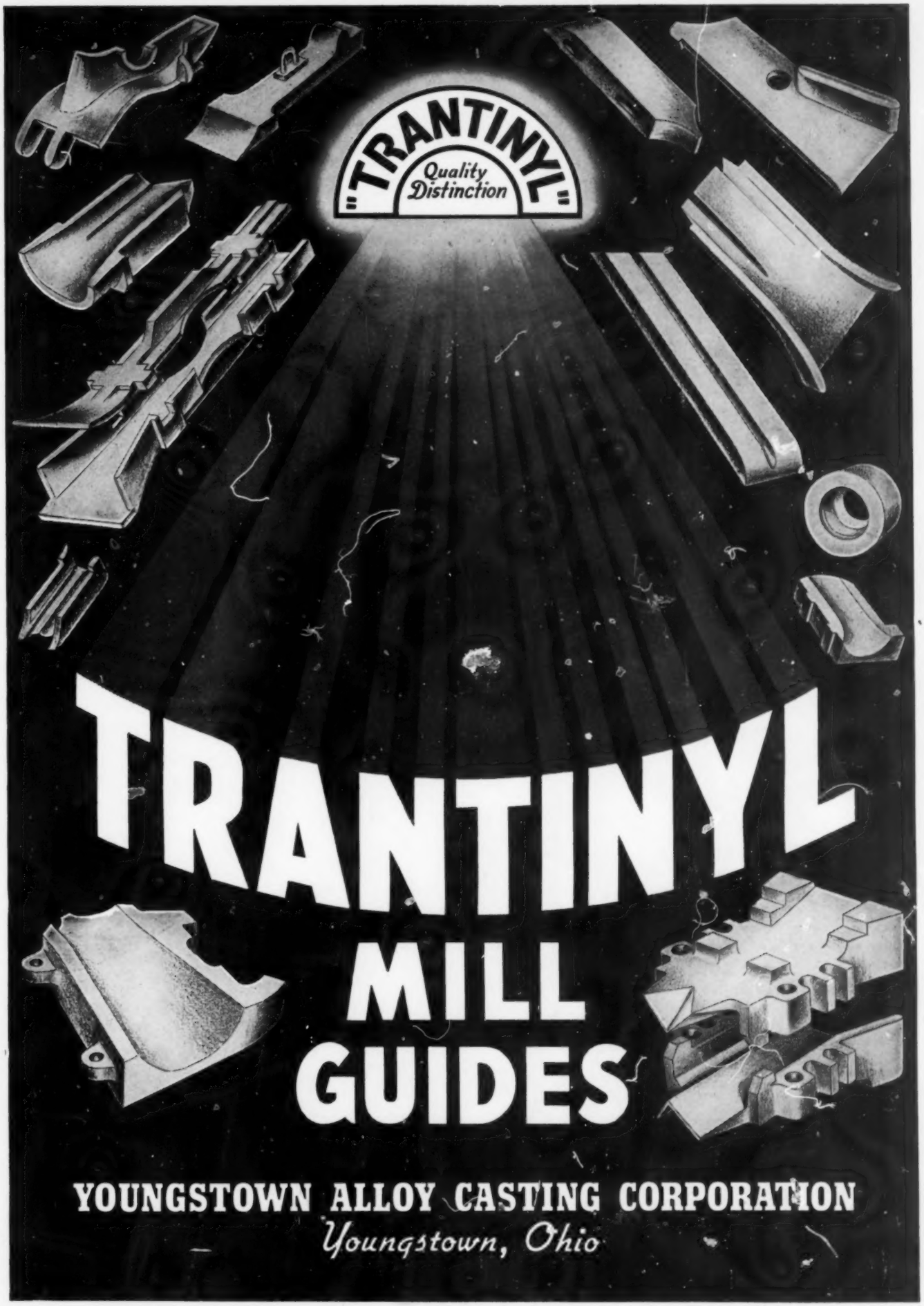
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Quality Distinction
TRANTINYL
MILL GUIDES
YOUNGSTOWN ALLOY CASTING CORPORATION
Youngstown, Ohio

(*Continued from page 159*)

These oil-insulated transformers are hermetically sealed.

cover. Conduit connection to this junction box is carried under the top of the tank and through the side wall.

Radio interference and corona are kept to low levels in the new transformers by improved high-voltage bushings treated at critical points with a semi-conducting glaze. Visual corona is eliminated up to 85 kv by this method. High strength against surges is obtained by shielding design of the core and coils and static plates and rings. Both no-load and total losses in these transformers are lower than in previous designs due to the use of type "C" Hipersil cores. Weight and overall height are decreased.

Precipitation transformers are available in 5, 7½, 10, 15, and 25 kva sizes for 60,000-volt or 75,000-volt operation at 60 cycles. Other transformers in the same ratings are available for operation at 25 cycles.

FORK TRUCK USED FOR WIRE COIL HANDLING

▲ A 3-fold advantage resulting from the use of a fork truck was realized almost immediately following its installation in the plant of Johnson Steel and Wire Co., Akron, Ohio. The benefits realized are in each of the three major industrial handling operations—handling costs in receiving have been cut from approximately $17 to $1.40 in the unloading of boxcars; the "on schedule" movement through production has been a major factor in making possible a doubled production output; existing storage capacity has been increased 40 to 50 per cent.

Considerable quantities of wire are handled daily by the company. The manufacturer receives the greatest majority of the semi-finished wire in boxcars, the remainder arriving via highway trucks. A Baker 3000 lb capacity fork truck, with its forks brought together to form a ram, unloads and stores coils of the incoming wire in 45 minutes to an hour. When this operation was performed manually, it took four men working four to five hours to do the job with hand trucks. These coils of wire, each weighing about 300 lb, are now handled six at a time. The truck has also made it possible to stack the coils 2 and 3 high, thereby greatly increasing the capacity of the existing storage facilities.

Another very important advantage which has been made possible with the use of the trucks is that the boxcar can be unloaded almost im-

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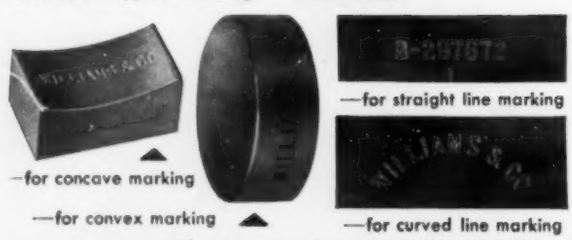
WEDGE GRIP
STEEL HAND STAMPS

Made with two or more characters, trade mark designs, Gothic, Roman, or script style lettering to suit any requirement. Sizes from 1/64" and up. Non-spalling, non-mushrooming features assure long, safe service on all types of marking.



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Write for quotation on your requirements.

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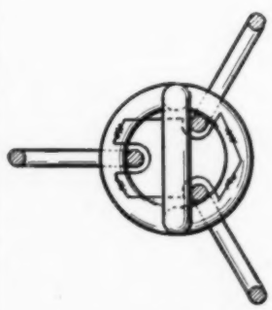
SAFETY STEEL STAMPS
105 East Carson Street · Pittsburgh 19, Pa.

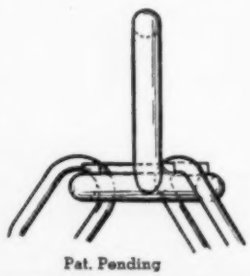
the MOST ECONOMICAL
SUSPENSION CHAIN
for hard, fast working magnets

Heat-treated high alloy steel PLUS the patented ring to eliminate rubbing and twisting gives Downtown Frictionless Magnet Suspension Chains up to 3 times the life of old-style suspension chains.



Locating Plate keeps magnet face level.

No more periodic annealing.



Pat. Pending

For these reasons Downtown Suspension Chains offer you best dollar value.

Each chain for 55 inch magnets is tested to 89,000 lbs. Each chain for 65 inch magnets is tested to 115,000 lbs. Don't delay! Write now for prices. Prompt shipment from stock.

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1836 EUCLID AVE. · CLEVELAND 15, OHIO

NEW ENGINEERING MATERIAL

REVOLUTIONARY

DEVELOPMENT IN THE CASTING INDUSTRY

DUCTILE CASTINGS

LICENSED UNDER PATENTS OF INTERNATIONAL NICKEL COMPANY

TENSILE STRENGTH 75,000 TO 90,000 PSI • ELONGATION 2% TO 10%
YIELD POINT 55,000 TO 65,000 POUNDS • BRINELL HARDNESS 175 TO 300
MODULUS OF ELASTICITY 25,000,000 POUNDS

WE ARE FURNISHING THE STEEL INDUSTRY CASTINGS WITH ABOVE PROPERTIES.
SEND US YOUR DRAWINGS AND INQUIRIES

OTHER PRODUCTS

HYDRAULIC SLAB AND BILLET PILERS
STRIP AND SHEET OILING EQUIPMENT
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TILTING TABLES—TRAVELING AND LIFTING TABLES
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STRIP STEEL COILERS AND REELS—SCRAP BALLERS
RAILROAD SPIKE FORMING MACHINES— ROLL LATHES
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ROLLING MILL TABLES—GEAR AND INDIVIDUAL MOTOR TYPES
MACHINERY BUILT TO CUSTOMER'S
DESIGN AND DETAIL DRAWINGS

The Youngstown Foundry & Machine Co.

Youngstown, Ohio

OVER SIXTY YEARS OF SERVICE TO THE STEEL INDUSTRY

mediately upon its arrival at the siding. This is highly important since extended exposure of the wire to the outdoor air causes it to rust very quickly. In addition, it is not necessary to remove men from other tasks to unload the car.

Because of the rather limited amount of "free" floor space in the drawing department the wire must be brought almost as it is needed by the draw benches to keep the machines busy. Here again the Baker fork truck has brought new economies. The former method of delivering the wire to the machines had been with hand trucks—a tedious back-breaking job which, because of its slowness, deprived the wire drawers of the benefits of the incentive wage system. With the aid of this single truck the production of the entire plant has been greatly increased.

In addition to the benefits already cited, safer and better working conditions have resulted, aisles are now kept clear, and the men removed from this heavy job are now on lighter, more productive work.

FREQUENCY INDUCTION FOR ELECTRIC WELD TUBE

▲ Frequency induction equipment is being developed for use in the continuous production of electric weld tubing and it is expected that the system will enable production of 200 ft of tubing per minute. This development is sponsored by the Ohio Crankshaft Co. and the Yoder Co. The electrical equipment was developed by the Reliance Electric and Engineering Company, the heat application was handled by Ohio Crankshaft and Yoder worked out the mechanical system of moving the pipe. It is said that the method will double production over previous methods of electric welding tubing and that it will turn out four times as much as for present gas welding.

A frequency of 10,000 cycles is used which fuses the metal together at temperatures between 2300 and 2600 F. It is expected that the first production unit will be in operation in January. At the present time the system works only with low carbon steel tubing, but in the future it is believed that it can be applied to non-ferrous metals and stainless steels.

There are also definite possibilities for induction heating in combination with the fuel fired heating furnace of the Fretz-Moon tube mill. The fuel-fired furnace would be used to heat the entire strip to permit forming while the induction method would supply the local heat at the edges for the welding operation. This would reduce maintenance problems on the fuel-fired furnace.

CRANE BRIDGE STOP USES DYNAMIC BRAKING

▲ For use on the bridge motions of high speed cranes and for man-trolleys of ore and coal bridges, etc., Electric Controller & Mfg. Co., has announced the safety dynamic braking crane bridge-stop.

With present cranes designed for fast running speeds, crane operators

Dravo Crane Cab Coolers are simple to install; all parts are readily accessible for servicing.

DRAVO CRANE CAB COOLERS
ASSURE OPERATOR COMFORT

Operators of hot-metal cranes are more alert and efficient when you protect them from fatigue and discomfort by air conditioning the cabs with Dravo Crane Cab Coolers.

Completely self-contained, and requiring only an electrical connection, the Dravo Crane Cab Cooler provides complete air conditioning:

Cooling
Fume and Odor Removal
Dust Filtering
Continuous Ventilation
Dehumidifying
Winter Heating

DRAVO CORPORATION
PITTSBURGH • PHILADELPHIA • CLEVELAND • NEW YORK
CHICAGO • DETROIT • ATLANTA • BOSTON
Sales Representatives in Principal Cities

DRAVO

YES,
YOU CAN GET FALCON
CASTING QUALITY AND PROMPT DELIVERY ON THE KINNEY
REFRACTORY LINED TUYERE COOLER

• Falcon's specialized non-ferrous service to the Steel Industry includes licensed production of this advanced design in tuyere coolers. The refractory, which may be brick or quick setting cement, protects the tuyere cooler from hot metal which may cut back through the tuyere and blow-pipe. Covered by Patent Application Serial No. 530153.

• High Grade Copper Cooling Castings for Blast Furnace Requirements.
• Standard and Special Tuyeres.
• Bronze Bearings of any type but specialization in Steel Mill Rolling Bearings.
• Electrodes used in production of electrically welded pipe or tubing.
• Copper Welding Balls. U. S. Patent No. 1,973,680.

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often use the reverse-power plugging method of control for stopping the bridge motion of cranes and generally use the foot-brake for final stopping or holding the crane in position. Should power fail or the overload relays on the controller trip at the instant of plugging, the operator may not grasp the situation in time to apply the foot-brake and avoid a collision with another crane on the same runway or prevent his crane from crashing into the runway bumpers. When power fails or overload relays trip, the EC&M dynamic braking bridge-stop control converts the driving motors into generators to stop the crane quickly.

This control is designed for cranes having bridge or trolley motions operated by a single motor, by two motors in series, or by two or more motors connected in parallel. Automatic deceleration is an additional feature which is available to provide more effective braking throughout the entire stopping period. The control may also be arranged for service braking applied by the operator in addition to automatic application on power failure.

LEVER-OPERATED COLLET RAISES LATHE RANGE

▲ Engineers of Monarch Machine Tool Co. have developed a new lever-operated collet attachment providing up to 1⅛ in. round bar stock capacity for application on all Monarch Series 60 engine and toolroom lathes, the company has announced.

Suitable for installation on these machines at the factory only, the attachment has been so designed that it can be used for either draw-in or pusher-type collets. Both types are identical except for the drawbar, collets and spindle nose adapter thereby assuring quick conversion by the user from one type collet to the other.

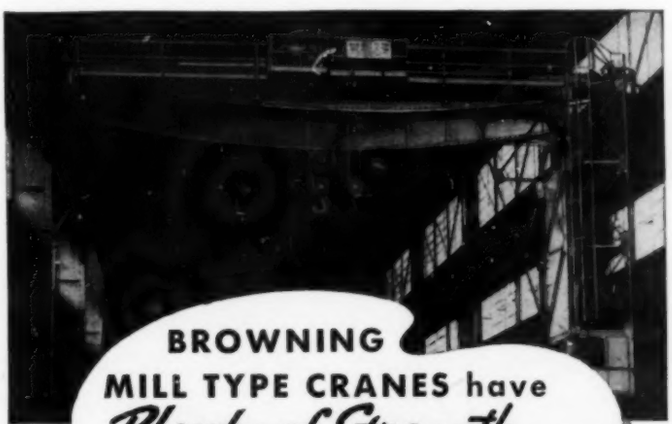
Removal of the drawbar is easily accomplished when this new lever-operated collet attachment is in use, the manufacturer further points out. Also, the relation between the attachment and the collet itself can be adjusted readily from the exterior of the machine at the left-hand end of the headstock. The operating lever, extending up over the top of the headstock, is positioned conveniently to the operator standing in his normal operating position.

STANDARD OXYGEN UNITS HAVE 10-TON CAPACITY

▲ Stacey Dresser Engineering, a division of Stacey Brothers Gas Construction Co., has announced a new standard oxygen plant capable of producing 10 net tons per day of oxygen. This plant produces at 95 per cent purity (10.5 gross tons per day) using normal atmospheric clean air as raw material.

The unit is small and compact and can be accommodated on only 32 ft x 24 ft floor space. The cold box which is 10 ft x 8 ft x 32 ft encloses three quarters of the fractionating tower and all exchangers and cold piping.

The unit can be erected simply, as the piping is prefabricated and there are only five pieces of equipment outside the cold box. The units are easy to maintain and operate. Stacey Dresser has engineered custom-built plants in sizes up to 1000 tons per day.



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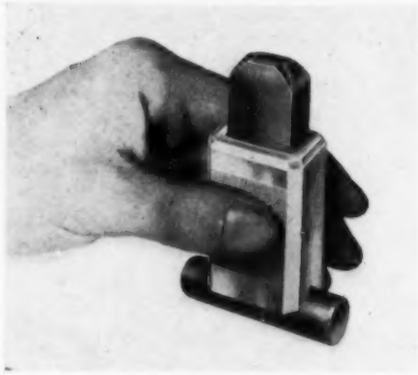
STEEL STAMP HOLDER FOR ROUNDS AND FLATS

▲ Another new marking device has been added to the popular series of "Luminum-Line" safety tools developed by the M. E. Cunningham Co., for use with solid steel hand stamps. It is the "Set-Rite" stamp holder for marking rounds, flats, and other industrial shapes.

The new Cunningham "Set-Rite" stamp holder is cast from tough, light-weight aluminum, and is specially designed to facilitate deep, clear and even marking. Holder sides are knurled to assure an absolute grip, and the holder bottom features a "V" slot to permit positive setting.

Holders are available in standard and deluxe models. On the standard model a pin is used to hold the stamp in place while the deluxe model utilizes a friction spring. The friction spring is especially valuable if several different stamps are to be used in the same holder. Stamps are not slotted so that they can be quickly changed.

The holder is made in a wide range of sizes to accommodate most standard solid steel hand stamps, and special-sized holders can also be made to order. For extra large, heavy-duty stamping, holders are furnished with metal handles.



TUBE BENDING MACHINE HAS SIX AUTOMATIC STOPS

▲ New development in high speed hydraulic automatic universal tube and miscellaneous bending machine is announced by the Acme-Winter Corp.

These machines are furnished in several sizes for bending up to and including 3 in. outside diameter, ¼ in. wall or larger die tubes of the same area. The short bending head allows the operator to work in front of the machine.

The standard machines are equipped with 6 automatic stops for various degree of bends, and are indexed automatically.

The machine bends either right or left hand with the standard dies, and can be furnished with hand control and automatic mandrel ejector.

Rigidity and flexibility of die setting and operation has had special attention in its construction. Machines can be furnished with special extension tables and adjustable gages to suit customers' needs.

The machine is a single unit having the motor and oil tank situated in the base or pan and all valves and pipe connections are above the base to prevent oil from getting on the floor, should leaks occur.

The bending head is made of cast steel, is fitted with needle bearings and operated by rack and pinion.

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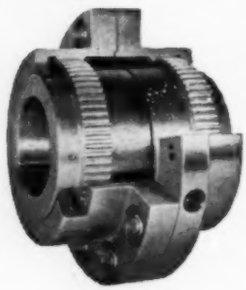

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Address DURABLA Engineering Department for Information and Bulletin No. 9512

* Patent Numbers 2090486, 2117504

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the Corporation President

WHO ALMOST SLEPT TOO LONG

T. M. Stanton* was having a nightmare. For months he'd been preoccupied with the production problems of Empire Gadgets, Inc. So preoccupied, he'd even half-admitted to himself that he was devoting far less thought to national problems than a leading citizen should. But the urgency of his immediate interests kept shoving these concerns into his subconscious mind. Now they were torturing his sleep.

"T. M., old boy," one spectre was saying, "how would you like a nice black depression to come along and swallow up your whole company?" And a green-eyed ogre leered, "While you're neglecting your free-enterprise system, we're moving in with *another* system!"

Stanton's body lurched. "No!" he thundered. Awakened, he scratched his head, murmuring, "Gad, what a dream! H-m-m—wonder what sort of contribution I ought to be making . . ."

Here's Something, Mr. President, You Ought to Do Right Away!

Check up on the status of the Payroll Savings Plan in your company. By making U. S. Savings Bonds easily available to your employees "on the installment plan," it benefits not only the employees but your business and the nation as well! Here's how:

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(3) The Plan helps to spread the national debt and thus helps secure your business future. How this works is clearly and briefly described in the free brochure shown below.

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Employees still want the benefits of the Payroll Savings Plan. In fact, they *need* the P. S. P., because banks don't sell Bonds on a partial-payment plan—which is the way most workers prefer to buy them. But war-time emotional appeals are gone. Human nature being what it is, the success of the Plan in your company is liable to dwindle unless a responsible executive *keeps promoting it.*

So—today—*check up* on the status of the Payroll Savings Plan in your company. *Act* on your responsibility to see that it is vigorously maintained.

The State Director will gladly help.

Be sure to read this! *"The National Debt and You," a 12-page brochure, brings you the views of W. Randolph Burgess, Vice Chairman of the Board of The National City Bank of New York —and of Clarence Francis, Chairman of the Board, General Foods Corporation. Request your copy from the Treasury Department's State Director, Savings Bonds Division.*

**This one is fictitious—but it might be any corporation president.*

The Treasury Department acknowledges with appreciation the publication of this message by

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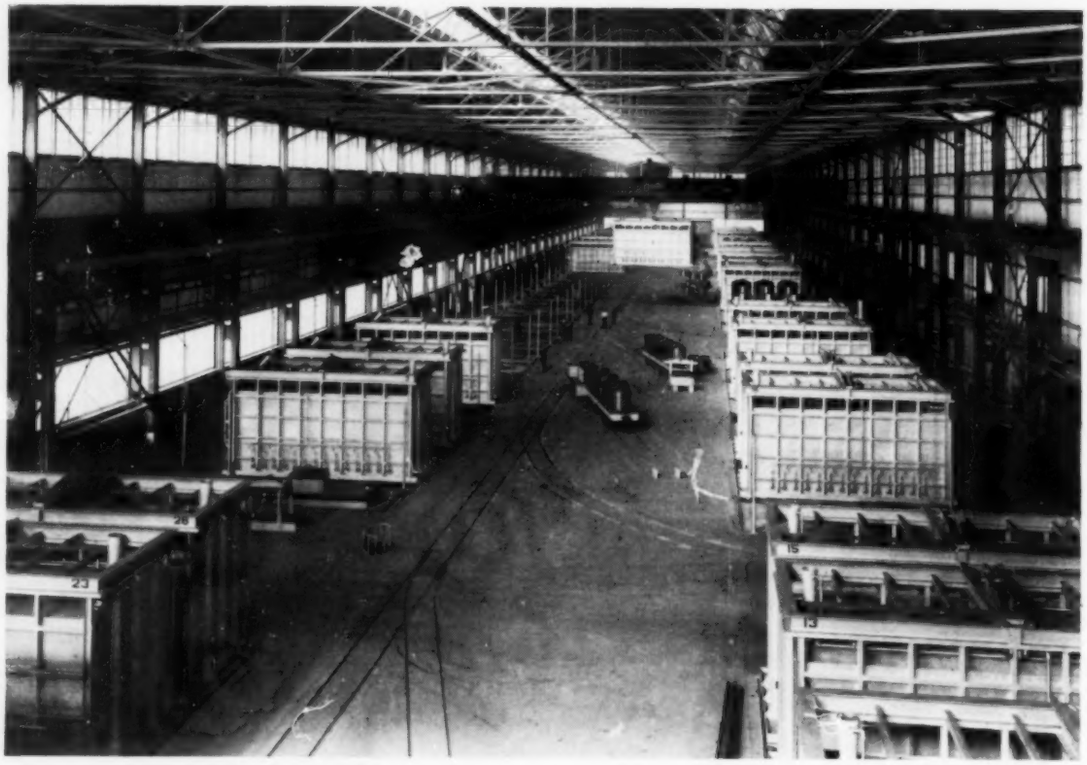

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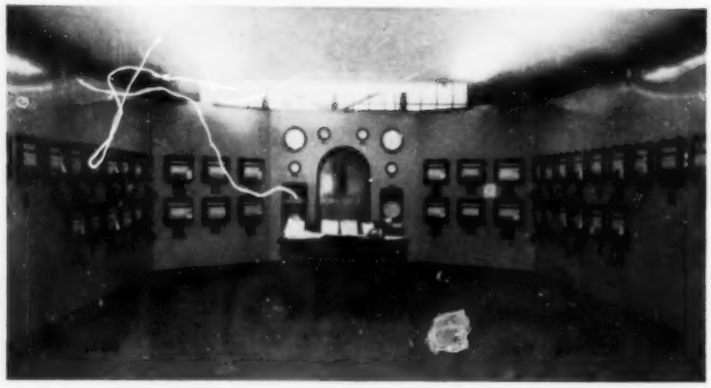

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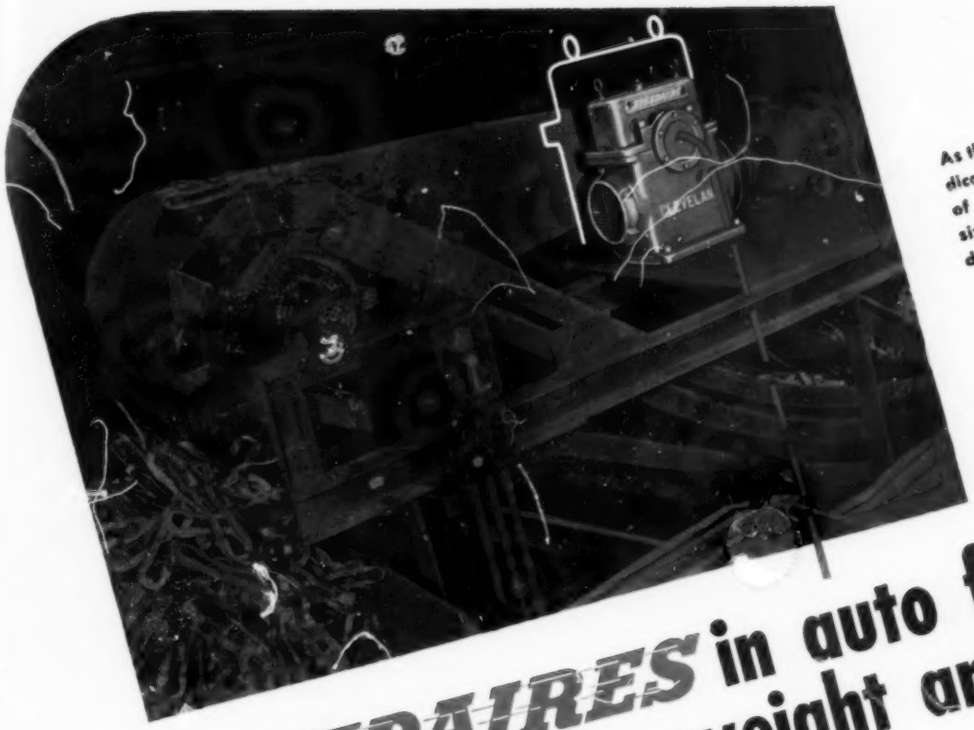

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THIRTEEN Speedaires are at work in this auto forge shop. Three drive cold scrap trim conveyors, two operate scrap rattlers, and eight drive cold billet conveyors. For each application, Speedaire offered three big advantages—a saving in cost, a saving in weight, and a saving in space occupied. The unit shown here, driving a scrap conveyor, weighed 25% less, took 40% less space than a conventional worm-gear unit required to do the work, and saved $84.50.

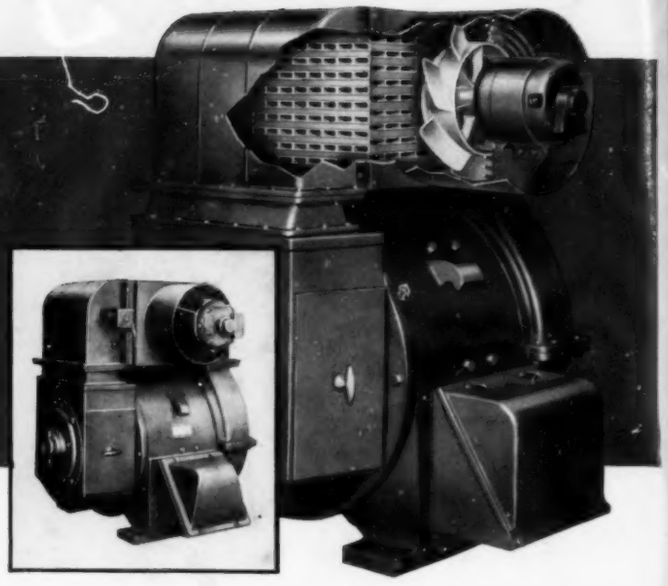
Speedaire is Cleveland's new fan-cooled worm-gear speed reducer. Because it is fan-cooled, Speedaire will do more work—will deliver up to *double the horsepower* of standard worm units of equal frame size, at usual motor speeds. It can be installed economically on many applications where other types have been used heretofore—giving you the advantages of a compact right-angle drive. Speedaire gives the same long, trouble-free service characteristic of all Clevelands.

For full description, send for Catalog 300. The Cleveland Worm & Gear Co., 3278 E. 80th St., Cleveland 4, Ohio.

Affiliate: The Farval Corporation, Centralized Systems of Lubrication. In Canada: Peacock Brothers Limited.

CLEVELAND
Worm & Gear
Speed Reducers

Dust and dirt can't stop them!



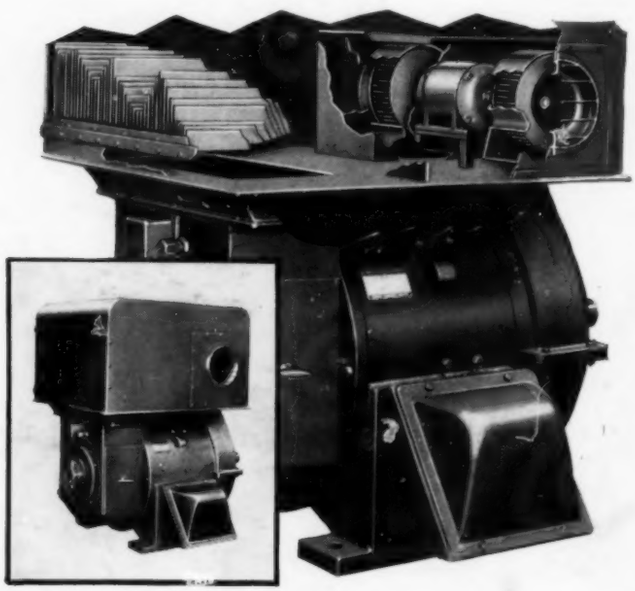
unit-cooled D-C MOTORS

Single-blower type for normal speed operation In this standard G-E motor, the unit cooler consists of alternate air passages placed at right angles to each other. Clean motor air, kept in motion by a fan on the main motor shaft, circulates through one set of passages in an enclosed system. Cool outside air, drawn into the cooler by a blower separately motor-driven, flows through another set of passages and absorbs the heat from the internal air stream. Motor air, never in contact with contaminated outside air, is always clean.

When you need reliable d-c power on dirty jobs, without worrying about maintenance, here's the answer—General Electric standard, totally enclosed, unit-cooled d-c motors. Atmospheric conditions that soon stop an open motor—dust, dirt, dampness, metal particles or oily vapors—can't affect their operation. Motor failures are reduced, machined output increased.

Installation is no problem. Motor and cooler, as a unit, come ready to install, with no auxiliary ventilating fixtures needed. Easy access to commutator, brushes and brush rigging simplifies maintenance. And power cost is less, especially where you use a wide speed range, because motor heat is quickly dissipated.

Better protected and better cooled, these tough G-E motors are available in ratings from 15 to 200 hp. See your G-E representative for more information, or write for Bulletin GEA-4469. *Apparatus Dept., General Electric Company, Schenectady 5, N. Y.*



Double-blower type for continuous low speeds New—a totally enclosed standard G-E motor that can't run a fever! Without danger of overheating, it delivers full torque continuously, even at very low speeds. Key to its operation is a new development—ventilation entirely independent of motor speed. Two blowers, mounted on opposite shaft extensions of a single auxiliary motor running at constant speed, provide full ventilation at all times. One circulates internal air and the other external air through alternate vertical passages.

GENERAL ELECTRIC

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